

Visible Light-Promoted Selenylative Spirocyclization of Biaryl Ynones toward the Formation of Selenated Spiro[5.5]trienones

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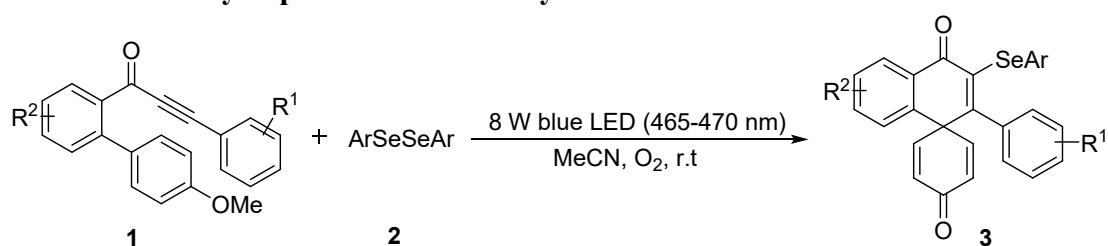
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1. General information

Unless otherwise stated, all commercial materials and solvents were used directly without further purification. ^1H and ^{13}C NMR spectra were measured on a 400 MHz Bruker spectrometer (^1H 400MHz, ^{13}C 100MHz, ^{19}F NMR 376 MHz), using CDCl_3 (spectra were referenced to the solvent peaks ^1H : residual $\text{CDCl}_3 = 7.26$ ppm, ^{13}C : $\text{CDCl}_3 = 77.0$ ppm)) as the solvent. High-resolution mass spectra (HRMS) were measured on ESI-TOF. Column chromatography was performed on silica gel (70-230 mesh ASTM) using the reported eluent. Thin-layer chromatography (TLC) was carried out on 4×5 cm plates with a layer thickness of 0.2 mm (silica gel 60 F254). Photochemical reactions were performed with a LED reactor WP-TEC-1020HSL (WATTCAS, China). Starting materials diselenides **2**, biaryl ynones **1** were prepared according to the literatures.^{S1,S2}

2. General catalytic procedure for the synthesis of **3**



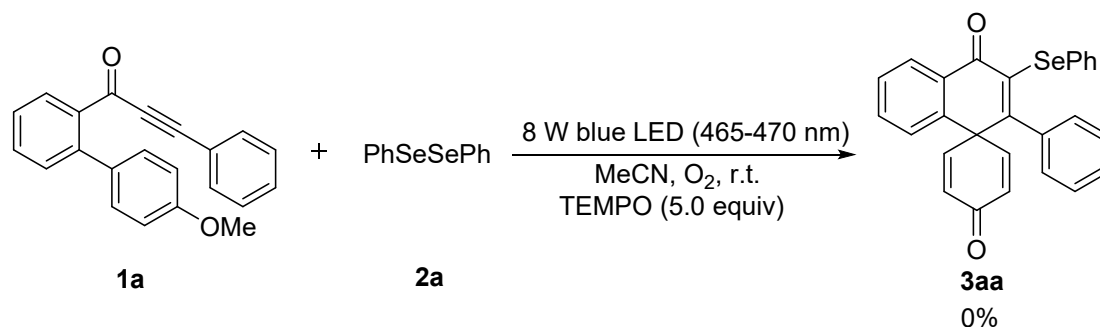
Biaryl ynones **1** (0.2 mmol), diselenides **2** (0.4 mmol), and 1.5 mL MeCN were added in a quartz tube. Then the mixture was stirred at room temperature (rt) for 12 h in the photochemical reactor with 8 W blue LED as light source under O_2 atmosphere. After completion of the biaryl ynones, the solvent was removed under reduced pressure by rotary evaporator. Then, the residue was purified by silica gel column chromatography to give the desired products **3**.



Figure. S1 The WP-TEC-1020HSL photochemical reaction system with the blue light LED

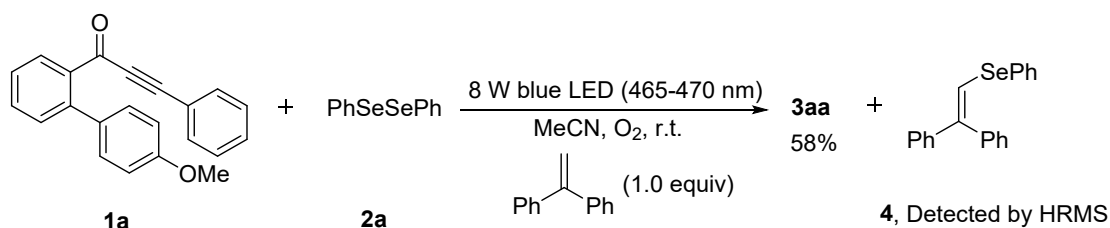
3. Mechanism experiments and large-scale synthesis of **3aa**

(1) Trapping experiment with 2,2,6,6-tetramethylpiperidin-1-oxyl (TEMPO)



Biaryl ynone **1a** (0.2 mmol), diphenyl diselenide **2a** (0.4 mmol), TEMPO (1 mmol, 5.0 equiv) and 1.5 mL MeCN were added in a quartz tube. Then the mixture was stirred at rt for 12 h in the photochemical reactor with 8 W blue LED as light source under O₂ atmosphere. The resulting mixture was monitored by TLC.

(2) Trapping experiment with ethene-1,1-diyldibenzene



Biaryl ynone **1a** (0.2 mmol), diphenyl diselenide **2a** (0.4 mmol), ethene-1,1-diyldibenzene (0.2 mmol, 1.0 equiv) and 1.5 mL MeCN were added in a quartz tube. Then the mixture was stirred at rt for 12 h in the photochemical reactor with 8 W blue LED as light source under O₂ atmosphere. The solvent was removed under reduced pressure, purification was performed by flash column chromatography on silica gel with petroleum ether/ethyl acetate as eluent to give the corresponding compound **3aa**, and **4** was detected by HRMS (Figure S2). HRMS (ESI) *m/z* calcd for C₂₀H₁₇Se [M+H]⁺ 337.0490, found 337.0489.

Sample Name	Sample4	Position	P1-44	Instrument Name	Instrument 1
User Name		Inj Vol	5	InjPosition	
Sample Type	Sample	IRM Calibration Status	Success	Data Filename	c-se-1.d
ACQ Method	MeOH 100 3min.m	Comment		Acquired Time	11/1/2021 4:02:46 PM

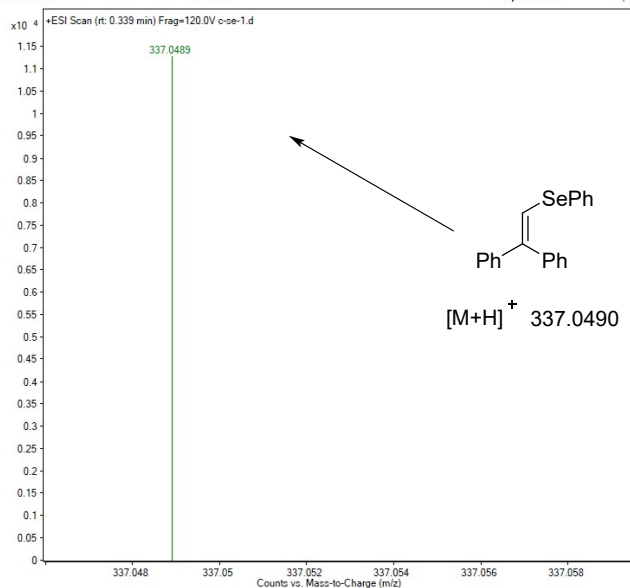
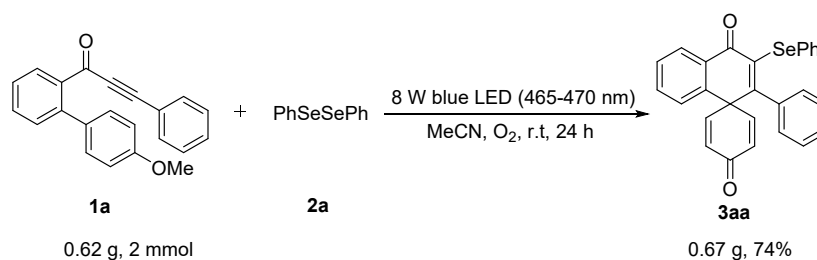


Figure. S2

(3) Large-scale synthesis of **3aa**



Biaryl ynone **1a** (2 mmol), diphenyl diselenide **2a** (4 mmol), and 4 mL MeCN were added in a quartz tube. Then the mixture was stirred at rt for 24 h in the photochemical reactor with 8 W blue LED as light source under O₂ atmosphere. After completion of the biaryl ynone, the solvent was removed under reduced pressure by rotary evaporator. Then, the residue was purified by silica gel column chromatography to give the desired products **3aa**.

4. X-ray data of compound **3ga** and **3af**

Single crystal suitable for X-ray diffraction experiment was obtained by slow evaporation of DCM/*n*-hexane (1:10, V/V) solution containing the compound **3ac** and **3af**.

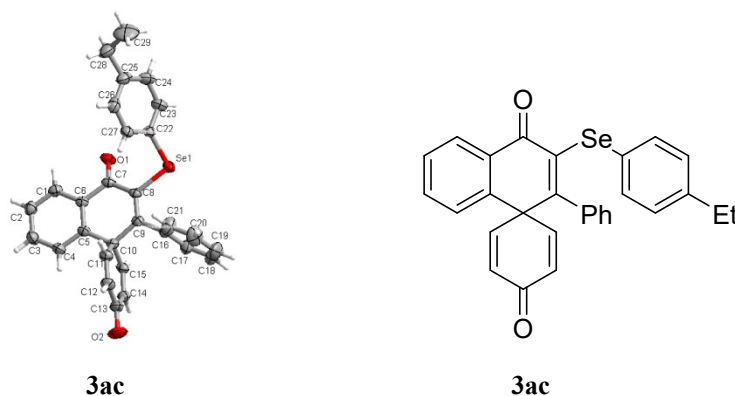
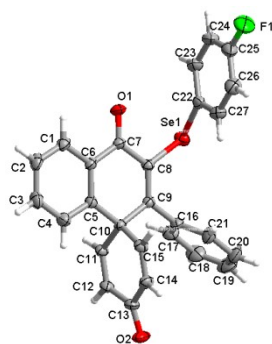


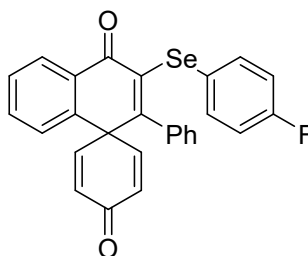
Figure S1. X-ray molecular structure of **3ac with the probability at 50% level.**

Table 1 Crystal data and structure refinement for 3ac.

Empirical formula	C ₂₉ H ₂₂ O ₂ Se
Formula weight	481.42
Temperature/K	293(2)
Crystal system	triclinic
Space group	P-1
a/Å	9.6751(8)
b/Å	10.1384(10)
c/Å	13.4857(12)
α /°	107.731(8)
β /°	109.770(8)
γ /°	93.109(7)
Volume/Å ³	1167.3(2)
Z	2
ρ calcd/cm ³	1.370
μ /mm ⁻¹	2.352
F(000)	492.0
Crystal size/mm ³	0.16 × 0.12 × 0.1
Radiation	CuKα (λ = 1.54184)
2θ range for data collection/°	7.418 to 134.15
Index ranges	-11 ≤ h ≤ 7, -12 ≤ k ≤ 12, -14 ≤ l ≤ 16
Reflections collected	8277
Independent reflections	4167 [Rint = 0.0409, Rsigma = 0.0542]
Data/restraints/parameters	4167/4/298
Goodness-of-fit on F ²	1.064
Final R indexes [I ≥ 2σ (I)]	R1 = 0.0455, wR2 = 0.1041
Final R indexes [all data]	R1 = 0.0626, wR2 = 0.1160
Largest diff. peak/hole / e Å ⁻³	0.26/-0.40



3af

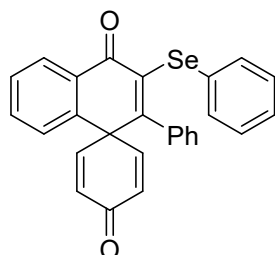


3af

Figure S2. X-ray molecular structure of 3af with the probability at 50% level.

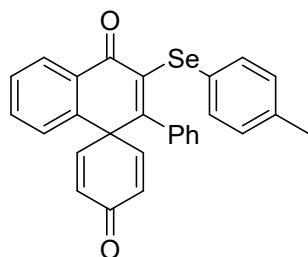
5. Characterization of compounds 3

2'-Phenyl-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3aa)^{S3,S4}



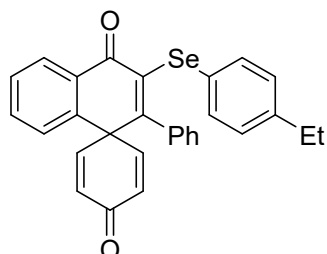
Yellow solid. 76.5 mg, Yield: 82%. mp 205-207 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.27 (d, *J* = 7.6 Hz, 1H), 7.56 (dt, *J* = 23.7, 7.3 Hz, 2H), 7.33 – 7.10 (m, 9H), 6.94 (d, *J* = 7.1 Hz, 2H), 6.76 (d, *J* = 9.1 Hz, 2H), 6.32 (d, *J* = 9.1 Hz, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 184.7, 180.6, 158.6, 148.5, 138.0, 137.9, 137.2, 133.4, 133.0, 130.7, 130.1, 130.0, 129.2, 129.0, 128.5, 128.1, 127.8, 127.4, 127.2, 52.6. HRMS (ESI) *m/z* calcd for C₂₇H₁₈NaO₂Se [M+Na]⁺ 477.0364, found 477.0366.

2'-Phenyl-3'-(*p*-tolylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ab)



Yellow solid. 71.1 mg, Yield: 76%. mp 191-193 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.27 (d, *J* = 7.7 Hz, 1H), 7.56 (dt, *J* = 22.0, 7.4 Hz, 2H), 7.31 – 7.16 (m, 6H), 6.95 (t, *J* = 7.1 Hz, 4H), 6.75 (d, *J* = 9.3 Hz, 2H), 6.32 (d, *J* = 9.3 Hz, 2H), 2.30 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 184.7, 180.7, 158.0, 148.5, 138.0, 137.9, 137.4, 137.3, 133.4, 133.3, 130.1, 129.8, 129.1, 128.5, 128.5, 128.0, 127.7, 127.5, 126.8, 52.5, 21.1. HRMS (ESI) *m/z* calcd for C₂₈H₂₀NaO₂Se [M+Na]⁺ 491.0521, found 491.0523.

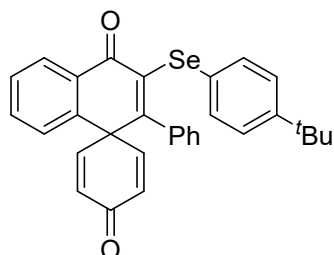
3'-((4-Ethylphenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ac)



Yellow solid. 78 mg, Yield: 81%. mp 188-189 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.27 (d, *J* = 7.7 Hz, 1H), 7.55 (dt, *J* = 14.9, 7.2 Hz, 2H), 7.31 – 7.24 (m, 2H), 7.22 (d, *J* = 7.3 Hz, 4H), 6.96 (dd, *J* = 13.8, 7.5 Hz, 4H), 6.75 (d, *J* = 9.4 Hz, 2H), 6.31 (d, *J* = 9.3 Hz, 2H), 2.58 (q, *J* = 7.5 Hz, 2H), 1.21 (t, *J* = 7.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 184.7, 180.7, 157.9, 148.6, 143.6, 138.0, 138.0,

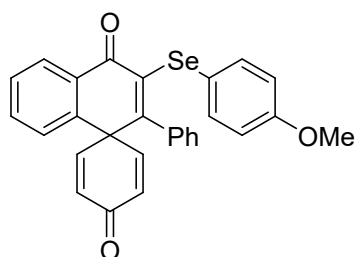
137.5, 133.5, 133.3, 130.1, 130.1, 129.1, 128.6, 128.5, 128.4, 128.1, 127.7, 127.5, 127.0, 52.6, 28.5, 15.5. HRMS (ESI) m/z calcd for $C_{29}H_{22}NaO_2Se$ $[M+Na]^+$ 505.0677, found 505.0681.

3'-((4-(Tert-butyl)phenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ad)



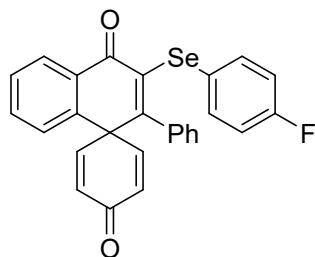
Yellow solid. 61.2 mg, Yield: 60%. mp 171-173 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.30 (d, $J = 7.6$ Hz, 1H), 7.57 (dt, $J = 19.4, 7.3$ Hz, 2H), 7.31 – 7.11 (m, 9H), 6.91 (d, $J = 7.6$ Hz, 2H), 6.74 (d, $J = 9.3$ Hz, 2H), 6.31 (d, $J = 9.3$ Hz, 2H), 1.29 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.8, 180.8, 157.8, 150.4, 148.6, 137.9, 137.5, 133.3, 133.2, 130.1, 130.0, 129.1, 128.5, 128.4, 128.1, 127.7, 127.5, 126.7, 126.1, 52.6, 34.5, 31.3. HRMS (ESI) m/z calcd for $C_{31}H_{26}NaO_2Se$ $[M+Na]^+$ 533.0990, found 533.0992.

3'-((4-Methoxyphenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ae)^{S4}



Yellow solid. 61 mg, Yield: 63%. mp 163-165 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.26 (d, $J = 7.5$ Hz, 1H), 7.54 (dt, $J = 21.9, 7.1$ Hz, 2H), 7.27 – 7.21 (m, 6H), 6.94 (d, $J = 7.1$ Hz, 2H), 6.73 (d, $J = 9.3$ Hz, 2H), 6.68 (d, $J = 7.7$ Hz, 2H), 6.29 (d, $J = 9.3$ Hz, 2H), 3.76 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.8, 180.9, 159.3, 157.3, 148.6, 137.9, 137.9, 137.8, 135.9, 133.3, 130.0, 129.1, 128.5, 128.0, 127.7, 127.6, 120.3, 114.6, 55.3, 52.5. ^{77}Se NMR (114 MHz, $CDCl_3$) δ 349.44. HRMS (ESI) m/z calcd for $C_{28}H_{20}NaO_3Se$ $[M+Na]^+$ 507.0470, found 507.0472.

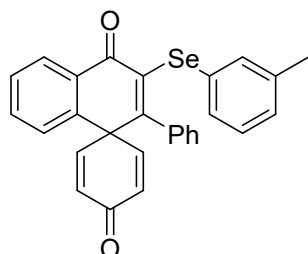
3'-((4-Fluorophenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3af)^{S4}



Yellow solid. 68.9 mg, Yield: 73%. mp 169-170 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, $J = 7.5$ Hz, 1H), 7.57 (dt, $J = 14.3, 6.8$ Hz, 2H), 7.29 – 7.24 (m, 6H), 6.94 (d, $J = 6.9$ Hz, 2H), 6.84 (t, $J = 7.9$ Hz, 2H), 6.74 (d, $J = 9.5$ Hz, 2H), 6.32 (d, $J = 9.6$ Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ

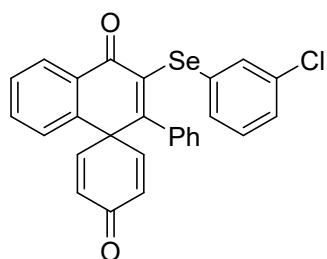
184.7, 180.7, 162.4 (d, $J = 247.6$ Hz), 157.9, 148.4, 138.0, 137.8, 137.5, 135.9 (d, $J = 8.0$ Hz), 133.5, 130.2, 129.9, 129.2, 128.6, 128.5, 128.1, 127.8, 127.5, 124.8 (d, $J = 3.4$ Hz), 116.1 (d, $J = 21.6$ Hz), 52.6. ^{19}F NMR (376 MHz, CDCl_3) δ -113.89. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{FNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 495.0270, found 4795.0272.

2'-Phenyl-3'-(*m*-tolylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ag)



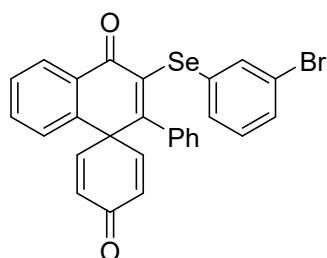
Yellow solid. 73 mg, Yield: 78%. mp 148-149 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.28 (d, $J = 7.7$ Hz, 1H), 7.56 (dt, $J = 22.6, 7.4$ Hz, 2H), 7.32 – 7.24 (m, 2H), 7.20 (t, $J = 7.5$ Hz, 2H), 7.10 (d, $J = 7.4$ Hz, 1H), 7.06 – 6.97 (m, 3H), 6.93 (d, $J = 7.7$ Hz, 2H), 6.76 (d, $J = 9.6$ Hz, 2H), 6.31 (d, $J = 9.7$ Hz, 2H), 2.23 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.7, 180.7, 158.1, 148.5, 138.6, 138.0, 137.9, 137.4, 133.8, 133.4, 130.4, 130.1, 130.0, 129.1, 128.8, 128.5, 128.4, 128.1, 128.1, 127.7, 127.5, 52.6, 21.3. HRMS (ESI) m/z calcd for $\text{C}_{28}\text{H}_{20}\text{NaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 491.0521, found 491.0523.

3'-((3-Chlorophenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ah)



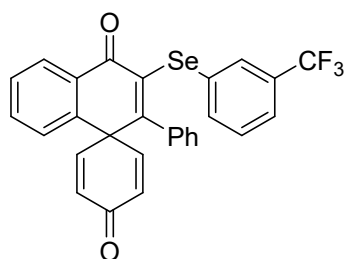
Yellow solid. 68.3 mg, Yield: 70%. mp 160-161 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.28 (d, $J = 8.9$ Hz, 1H), 7.58 (dt, $J = 14.1, 7.3$ Hz, 2H), 7.33 – 7.26 (m, 2H), 7.27 – 7.12 (m, 5H), 7.07 (t, $J = 8.0$ Hz, 1H), 6.93 (d, $J = 7.3$ Hz, 2H), 6.75 (d, $J = 10.0$ Hz, 2H), 6.33 (d, $J = 10.0$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.6, 180.5, 158.7, 148.3, 138.0, 137.6, 137.0, 134.4, 133.6, 132.8, 132.1, 131.2, 130.2, 129.9, 129.9, 129.2, 128.7, 128.5, 128.1, 127.8, 127.5, 127.4, 52.7. ^{77}Se NMR (114 MHz, CDCl_3) δ 372.05. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{ClNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 510.9975, found 510.9977.

3'-((3-Bromophenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ai)



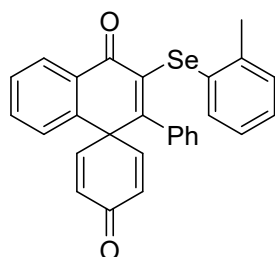
Yellow solid. 72.3 mg, Yield: 68%. mp 163-164 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.30 (d, *J* = 7.6 Hz, 1H), 7.59 (dt, *J* = 21.8, 7.3 Hz, 2H), 7.34 – 7.29 (m, 4H), 7.22 (t, *J* = 7.8 Hz, 3H), 7.01 (t, *J* = 7.8 Hz, 1H), 6.92 (d, *J* = 7.6 Hz, 2H), 6.75 (d, *J* = 9.8 Hz, 2H), 6.33 (d, *J* = 9.7 Hz, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 184.6, 180.5, 158.5, 148.2, 138.0, 137.6, 137.2, 135.7, 133.6, 132.4, 131.7, 130.4, 130.2, 129.9, 129.2, 128.7, 128.6, 128.1, 127.8, 127.4, 122.6, 52.7. HRMS (ESI) *m/z* calcd for C₂₇H₁₇BrNaO₂Se [M+Na]⁺ 554.9469, found 554.9471.

2'-Phenyl-3'-((3-(trifluoromethyl)phenyl)selanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3aj)



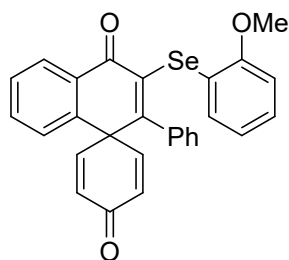
Yellow solid. 52.2 mg, Yield: 50%. mp 170-172 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.29 (d, *J* = 7.7 Hz, 1H), 7.59 (dt, *J* = 22.9, 7.4 Hz, 2H), 7.50 – 7.39 (m, 3H), 7.31 – 7.17 (m, 5H), 6.90 (d, *J* = 7.5 Hz, 2H), 6.74 (d, *J* = 9.1 Hz, 2H), 6.32 (d, *J* = 9.1 Hz, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 184.6, 180.6, 158.6, 148.2, 138.0, 137.6, 137.1, 136.5, 133.6, 131.6, 131.1 (q, *J* = 32.8 Hz), 130.3, 129.8 (q, *J* = 3.9 Hz), 129.8, 129.2, 129.2, 128.8, 128.5, 128.1, 127.8, 127.3, 124.07 (q, *J* = 3.7 Hz), 123.6 (q, *J* = 273.3 Hz), 52.7. ¹⁹F NMR (376 MHz, CDCl₃) δ -62.73. HRMS (ESI) *m/z* calcd for C₂₈H₁₇F₃NaO₂Se [M+Na]⁺ 545.0238, found 545.0239.

2'-Phenyl-3'-(*o*-tolylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ak)



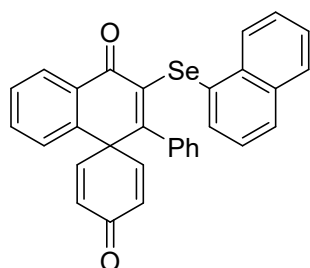
Yellow solid. 49.6 mg, Yield: 53%. mp 159-161 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.28 (d, *J* = 7.7 Hz, 1H), 7.57 (dt, *J* = 23.2, 7.4 Hz, 2H), 7.30 (d, *J* = 8.1 Hz, 2H), 7.25 (d, *J* = 7.2 Hz, 1H), 7.18 (dd, *J* = 13.1, 7.2 Hz, 3H), 7.12 – 7.06 (m, 2H), 6.95 – 6.90 (m, 3H), 6.76 (d, *J* = 9.5 Hz, 2H), 6.32 (d, *J* = 9.5 Hz, 2H), 2.26 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 184.7, 180.6, 158.0, 148.5, 139.6, 138.0, 137.8, 137.2, 133.4, 133.2, 131.9, 130.1, 130.0, 129.9, 129.1, 128.5, 128.5, 128.1, 127.7, 127.4, 127.2, 126.4, 52.7, 22.5. HRMS (ESI) *m/z* calcd for C₂₈H₂₀NaO₂Se [M+Na]⁺ 491.0521, found 491.0524.

3'-((2-Methoxyphenyl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3al)



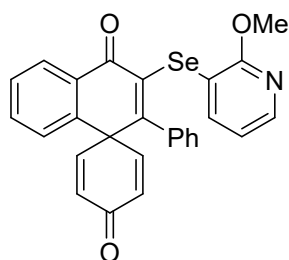
Yellow solid. 43.6 mg, Yield: 45%, mp 147-148 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.28 (d, $J = 7.4$ Hz, 1H), 7.57 (dd, $J = 15.5, 7.3$ Hz, 2H), 7.35 – 7.12 (m, 5H), 7.06 (d, $J = 7.2$ Hz, 1H), 6.97 (d, $J = 6.9$ Hz, 2H), 6.76 (t, $J = 11.0$ Hz, 4H), 6.33 (d, $J = 9.4$ Hz, 2H), 3.75 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.8, 180.4, 158.2, 157.3, 148.7, 137.9, 137.9, 136.0, 133.3, 131.9, 130.1, 129.1, 128.6, 128.5, 128.2, 128.0, 127.7, 127.2, 121.3, 120.3, 110.6, 55.6, 52.61. HRMS (ESI) m/z calcd for $\text{C}_{28}\text{H}_{20}\text{NaO}_3\text{Se}$ $[\text{M}+\text{Na}]^+$ 507.0470, found 507.0467.

3'-(Naphthalen-1-ylselanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3am)



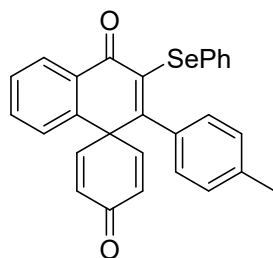
Yellow solid. 41.3 mg, Yield: 41%. mp 157-158 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.31 (d, $J = 7.5$ Hz, 1H), 8.06 (d, $J = 7.6$ Hz, 1H), 7.77 (d, $J = 7.4$ Hz, 1H), 7.69 (d, $J = 8.2$ Hz, 1H), 7.63 – 7.51 (m, 2H), 7.51 – 7.41 (m, 2H), 7.39 (d, $J = 7.1$ Hz, 1H), 7.25 (d, $J = 7.5$ Hz, 1H), 7.15 – 7.03 (m, 2H), 6.97 (t, $J = 7.4$ Hz, 2H), 6.63 (t, $J = 8.8$ Hz, 4H), 6.22 (d, $J = 9.2$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.8, 181.1, 156.6, 148.6, 138.0, 137.4, 137.2, 133.8, 133.8, 133.6, 133.4, 129.9, 129.8, 129.4, 129.1, 128.7, 128.6, 128.5, 128.2, 128.1, 127.7, 127.5, 127.1, 126.4, 126.1, 125.7, 52.9. HRMS (ESI) m/z calcd for $\text{C}_{31}\text{H}_{20}\text{NaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 527.0521, found 527.0522.

3'-((2-Methoxypyridin-3-yl)selanyl)-2'-phenyl-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3an)



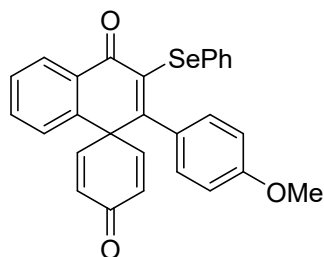
Yellow solid. 48.5 mg, Yield: 50%. mp 161-162 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.29 (d, $J = 7.6$ Hz, 1H), 7.97 (d, $J = 3.3$ Hz, 1H), 7.59 (dd, $J = 15.4, 7.5$ Hz, 2H), 7.39 – 7.13 (m, 5H), 6.95 (d, $J = 7.2$ Hz, 2H), 6.75 (d, $J = 9.4$ Hz, 2H), 6.66 (t, $J = 5.7$ Hz, 1H), 6.33 (d, $J = 9.4$ Hz, 2H), 3.87 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.7, 180.3, 161.3, 157.9, 148.4, 145.2, 140.8, 138.0, 137.5, 135.3, 133.5, 130.2, 129.8, 129.2, 128.7, 128.5, 128.1, 127.8, 127.2, 117.5, 115.0, 53.8, 52.7. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{19}\text{NNaO}_3\text{Se}$ $[\text{M}+\text{Na}]^+$ 508.0422, found 508.0423.

3'-(Phenylselanyl)-2'-(*p*-tolyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ba)^{S3}



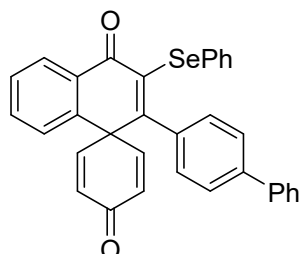
Yellow solid. 66.5 mg, Yield: 71%. mp 159-160 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.26 (d, *J* = 7.7 Hz, 1H), 7.56 (dt, *J* = 24.2, 7.4 Hz, 2H), 7.30 (t, *J* = 7.8 Hz, 3H), 7.21 – 7.13 (m, 3H), 7.03 (d, *J* = 7.7 Hz, 2H), 6.85 (d, *J* = 7.7 Hz, 2H), 6.76 (d, *J* = 9.5 Hz, 2H), 6.33 (d, *J* = 9.5 Hz, 2H), 2.34 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 184.8, 180.5, 158.8, 148.6, 138.4, 138.0, 137.1, 135.3, 133.3, 132.9, 130.8, 130.1, 129.1, 128.9, 128.5, 128.5, 128.1, 127.3, 127.1, 52.7, 21.3. ⁷⁷Se NMR (114 MHz, CDCl₃) δ 359.52. HRMS (ESI) *m/z* calcd for C₂₈H₂₀NaO₂Se [M+Na]⁺ 491.0521, found 491.0523.

2'-(4-Methoxyphenyl)-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ca)^{S3}



Yellow solid. 64.9 mg, Yield: 67%. mp 163-164 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.27 (d, *J* = 7.8 Hz, 1H), 7.56 (dt, *J* = 14.2, 7.9 Hz, 2H), 7.30 – 7.28 (m, 3H), 7.16 (dt, *J* = 14.1, 4.7 Hz, 3H), 6.88 (d, *J* = 8.6 Hz, 2H), 6.73 (dd, *J* = 9.2, 5.7 Hz, 4H), 6.33 (d, *J* = 9.9 Hz, 2H), 3.80 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 184.8, 180.7, 159.6, 158.2, 148.7, 138.0, 137.6, 133.3, 133.0, 130.9, 130.6, 130.1, 129.1, 128.9, 128.8, 128.5, 128.0, 127.2, 113.2, 55.2, 52.9. HRMS (ESI) *m/z* calcd for C₂₈H₂₀NaO₃Se [M+Na]⁺ 507.0470, found 507.0473.

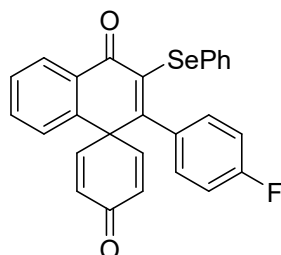
2'-([1,1'-Biphenyl]-4-yl)-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3da)



Yellow solid. 54 mg, Yield: 51%. mp 184-185 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.31 (d, *J* = 7.7 Hz, 1H), 7.66 – 7.51 (m, 4H), 7.47 (t, *J* = 7.4 Hz, 2H), 7.40 (d, *J* = 7.4 Hz, 3H), 7.34 – 7.09 (m, 6H), 6.99 (d, *J* = 7.8 Hz, 2H), 6.78 (d, *J* = 9.4 Hz, 2H), 6.35 (d, *J* = 9.4 Hz, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 184.8, 180.8, 157.7, 148.6, 141.1, 140.2, 138.0, 137.8, 136.9, 133.4, 133.3, 130.6, 130.2,

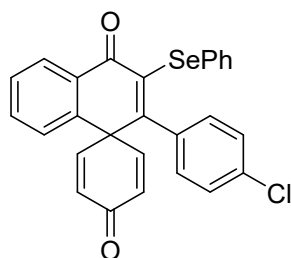
130.0, 129.2, 128.9, 128.8, 128.6, 128.1, 127.9, 127.7, 127.3, 127.1, 126.4, 52.7. HRMS (ESI) m/z calcd for $C_{33}H_{22}NaO_2Se$ $[M+Na]^+$ 553.0677, found 553.0681.

2'-(4-Fluorophenyl)-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ea)



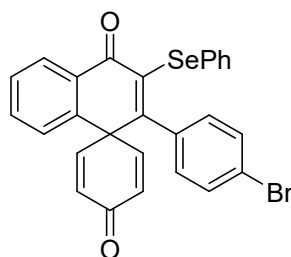
Yellow solid. 65.1 mg, Yield: 69%. mp 178-179 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.29 (d, $J = 7.7$ Hz, 1H), 7.58 (dt, $J = 21.7, 7.4$ Hz, 2H), 7.29 – 7.24 (m, 3H), 7.20 – 7.12 (m, 3H), 6.88 (d, $J = 6.7$ Hz, 4H), 6.72 (d, $J = 9.1$ Hz, 2H), 6.33 (d, $J = 9.1$ Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.5, 180.7, 162.4 (d, $J = 249.1$ Hz), 156.8, 148.4, 138.3, 137.9, 133.8 (d, $J = 3.6$ Hz), 133.5, 133.3, 130.5, 130.2, 129.8, 129.5 (d, $J = 8.3$ Hz), 129.2, 129.0, 128.6, 128.1, 127.4, 114.9 (d, $J = 21.8$ Hz), 52.6. ^{19}F NMR (376 MHz, $CDCl_3$) δ -112.26. HRMS (ESI) m/z calcd for $C_{27}H_{17}FNaO_2Se$ $[M+Na]^+$ 495.0270, found 4795.0271.

2'-(4-Chlorophenyl)-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3fa)



Yellow solid. 60.5 mg, Yield: 62%. mp 174-175 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.30 (d, $J = 7.7$ Hz, 1H), 7.58 (dt, $J = 21.0, 7.4$ Hz, 2H), 7.33 – 7.17 (m, 4H), 7.15 (d, $J = 8.0$ Hz, 4H), 6.83 (d, $J = 7.9$ Hz, 2H), 6.71 (d, $J = 9.4$ Hz, 2H), 6.33 (d, $J = 9.4$ Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.5, 180.7, 156.3, 148.2, 138.2, 137.8, 136.1, 134.5, 133.5, 133.4, 130.3, 130.3, 129.8, 129.2, 129.0, 128.9, 128.6, 128.1, 128.0, 127.4, 52.5. HRMS (ESI) m/z calcd for $C_{27}H_{17}ClNaO_2Se$ $[M+Na]^+$ 510.9975, found 510.9976.

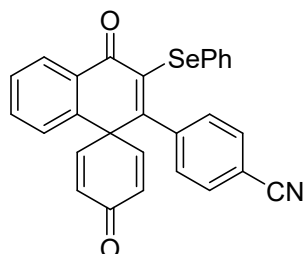
2'-(4-Bromophenyl)-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ga)



Yellow solid. 68.1 mg, Yield: 64%. mp 169-171 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.30 (d, $J = 7.6$ Hz, 1H), 7.58 (dt, $J = 20.6, 7.2$ Hz, 2H), 7.31 – 7.12 (m, 8H), 6.77 (d, $J = 7.8$ Hz, 2H), 6.71 (d, $J =$

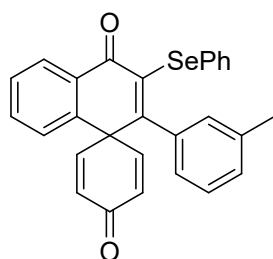
9.3 Hz, 2H), 6.33 (d, $J = 9.4$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.47 (s), 180.7, 156.2, 148.2, 138.2, 137.8, 136.6, 133.5, 133.5, 131.0, 130.3, 129.8, 129.2, 129.2, 129.0, 128.6, 128.1, 127.5, 122.8, 52.4. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{BrNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 554.9469, found 554.9472.

4-(4,4'-Dioxo-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-dien-2'-yl)benzotrile (3ha)^{S3}



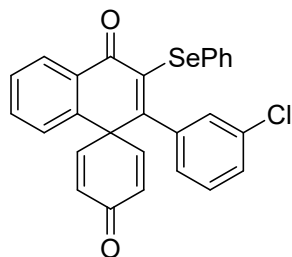
Yellow solid. 54.6 mg, Yield: 57%. mp 180-182 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.31 (d, $J = 7.6$ Hz, 1H), 7.60 (dt, $J = 21.0, 7.4$ Hz, 2H), 7.44 (d, $J = 7.6$ Hz, 2H), 7.28 (d, $J = 5.9$ Hz, 1H), 7.24 – 7.11 (m, 5H), 6.99 (d, $J = 7.6$ Hz, 2H), 6.71 (d, $J = 9.1$ Hz, 2H), 6.33 (d, $J = 9.2$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.1, 180.5, 154.9, 147.8, 141.8, 138.6, 137.7, 133.8, 133.6, 131.5, 130.5, 130.1, 129.5, 129.4, 129.2, 128.6, 128.6, 128.1, 127.7, 118.1, 112.2, 52.2. HRMS (ESI) m/z calcd for $\text{C}_{28}\text{H}_{17}\text{NNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 502.0317, found 502.0320.

3'-(Phenylselanyl)-2'-(*m*-tolyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ia)



Yellow solid. 73 mg, Yield: 78%. mp 167-169 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.27 (d, $J = 7.6$ Hz, 1H), 7.56 (dt, $J = 23.1, 7.2$ Hz, 2H), 7.29 (d, $J = 6.3$ Hz, 3H), 7.18 – 7.07 (m, 5H), 6.76 (t, $J = 8.5$ Hz, 3H), 6.67 (s, 1H), 6.32 (t, $J = 10.3$ Hz, 2H), 2.25 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.8, 180.7, 158.7, 148.6, 138.0, 137.9, 137.3, 137.1, 133.4, 133.1, 130.7, 130.0, 129.3, 129.1, 128.9, 128.5, 128.1, 128.0, 127.7, 127.2, 124.5, 52.6, 21.5. HRMS (ESI) m/z calcd for $\text{C}_{28}\text{H}_{20}\text{NaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 491.0521, found 491.0522.

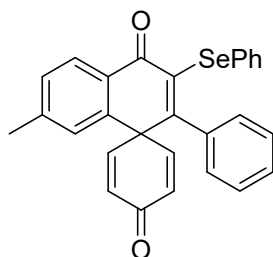
2'-(3-Chlorophenyl)-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ja)



Yellow solid. 60.5 mg, Yield: 62%. mp 171-173 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.30 (d, $J = 7.6$

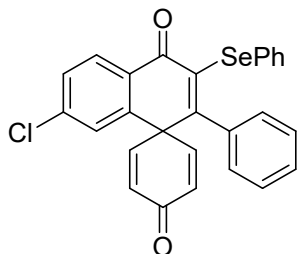
Hz, 1H), 7.58 (dt, $J = 21.2, 7.0$ Hz, 2H), 7.33 – 7.18 (m, 5H), 7.20 – 7.07 (m, 3H), 6.85 (s, 1H), 6.81 (d, $J = 7.6$ Hz, 1H), 6.72 (t, $J = 7.7$ Hz, 2H), 6.34 (dd, $J = 17.6, 9.7$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.5, 180.7, 155.9, 148.3, 148.0, 139.2, 138.3, 137.8, 133.7, 133.6, 130.4, 130.2, 130.1, 129.8, 129.3, 129.1, 129.1, 128.6, 128.6, 128.1, 127.8, 127.6, 125.8, 52.4. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{ClNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 510.9975, found 510.9974.

7'-Methyl-2'-phenyl-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ka)^{S3}



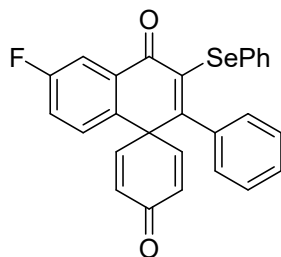
Yellow solid. 65.5 mg, Yield: 70%. mp 158-159 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.17 (d, $J = 7.6$ Hz, 1H), 7.34 (d, $J = 7.6$ Hz, 1H), 7.31 – 7.10 (m, 8H), 7.05 (s, 1H), 6.93 (d, $J = 5.9$ Hz, 2H), 6.75 (d, $J = 9.3$ Hz, 2H), 6.32 (d, $J = 9.3$ Hz, 2H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.9, 180.4, 158.2, 148.7, 144.5, 138.1, 137.9, 137.3, 132.9, 130.8, 130.3, 130.1, 129.0, 128.6, 128.5, 128.2, 127.7, 127.5, 127.1, 52.6, 21.8. HRMS (ESI) m/z calcd for $\text{C}_{28}\text{H}_{20}\text{NaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 491.0521, found 491.0520.

7'-Chloro-2'-phenyl-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3la)



Yellow solid. 70.3 mg, Yield: 72%. mp 151-153 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.21 (d, $J = 7.4$ Hz, 1H), 7.50 (d, $J = 8.1$ Hz, 1H), 7.34 – 7.10 (m, 9H), 6.93 (d, $J = 5.5$ Hz, 2H), 6.74 (d, $J = 9.0$ Hz, 2H), 6.35 (d, $J = 9.0$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.3, 179.8, 158.2, 147.6, 140.1, 139.8, 137.7, 137.2, 133.1, 130.6, 130.5, 130.2, 129.8, 129.0, 128.7, 128.4, 128.0, 127.8, 127.4, 127.4, 52.2. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{ClNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 510.9975, found 510.9975.

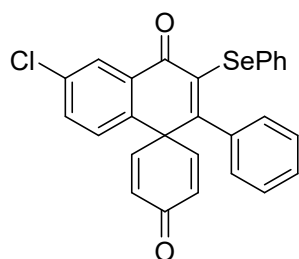
6'-Fluoro-2'-phenyl-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3ma)^{S3}



Yellow solid. 64.2 mg, Yield: 68%. mp 161-162 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.30 (s, 1H),

7.35 – 7.10 (m, 9H), 6.97 – 6.92 (m, 3H), 6.75 (d, $J = 9.0$ Hz, 2H), 6.34 (d, $J = 9.0$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.3, 179.5, 165.6 (d, $J = 256.9$ Hz), 158.3, 147.8, 141.1 (d, $J = 8.3$ Hz), 137.8, 137.2, 133.1, 131.7 (d, $J = 9.5$ Hz), 130.5, 130.4, 129.0, 128.6, 127.8, 127.4, 127.3, 126.6 (d, $J = 2.4$ Hz), 117.2 (d, $J = 22.1$ Hz), 114.7 (d, $J = 23.3$ Hz), 52.4. ^{19}F NMR (376 MHz, CDCl_3) δ -103.05. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{FNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 495.0270, found 4795.0272.

6'-Chloro-2'-phenyl-3'-(phenylselanyl)-4'H-spiro[cyclohexane-1,1'-naphthalene]-2,5-diene-4,4'-dione (3na)



Yellow solid. 63.4 mg, Yield: 65%. mp 157-158 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.23 (s, 1H), 7.54 (d, $J = 8.3$ Hz, 1H), 7.33 – 7.12 (m, 9H), 6.94 (d, $J = 6.9$ Hz, 2H), 6.72 (d, $J = 9.7$ Hz, 2H), 6.33 (d, $J = 9.7$ Hz, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 184.4, 179.5, 158.7, 147.8, 137.7, 137.1, 136.3, 135.7, 133.5, 133.2, 131.3, 130.4, 129.8, 129.1, 128.7, 128.2, 127.9, 127.4, 127.4, 52.2. HRMS (ESI) m/z calcd for $\text{C}_{27}\text{H}_{17}\text{ClNaO}_2\text{Se}$ $[\text{M}+\text{Na}]^+$ 510.9975, found 510.9978.

6. References

[S1] (a) *Green Chem.*, 2019, **21**, 3547. (b) *Adv. Synth. Catal.*, 2020, **362**, 3485.

[S2] (a) *Org. Lett.*, 2018, **20**, 2988. (b) *Org. Lett.*, 2021, **23**, 2548.

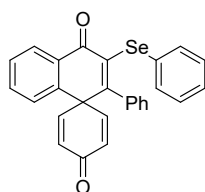
[S3] *J. Org. Chem.*, 2021, **86**, 17071.

[S4] *J. Org. Chem.*, 2022, **87**, 4273.

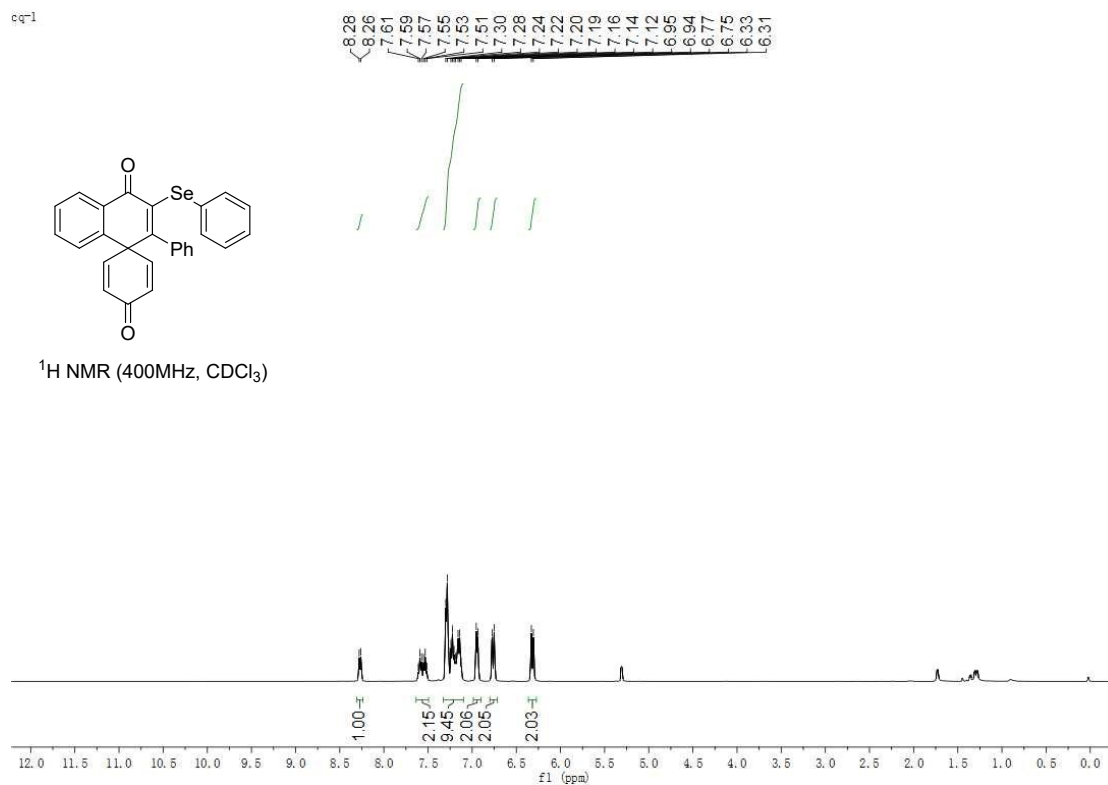
7. Copies of the ^1H , ^{13}C , ^{19}F and ^{77}Se NMR Spectra

^1H NMR spectrum of **3aa**

eq-1

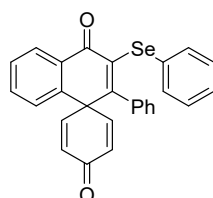


^1H NMR (400MHz, CDCl_3)

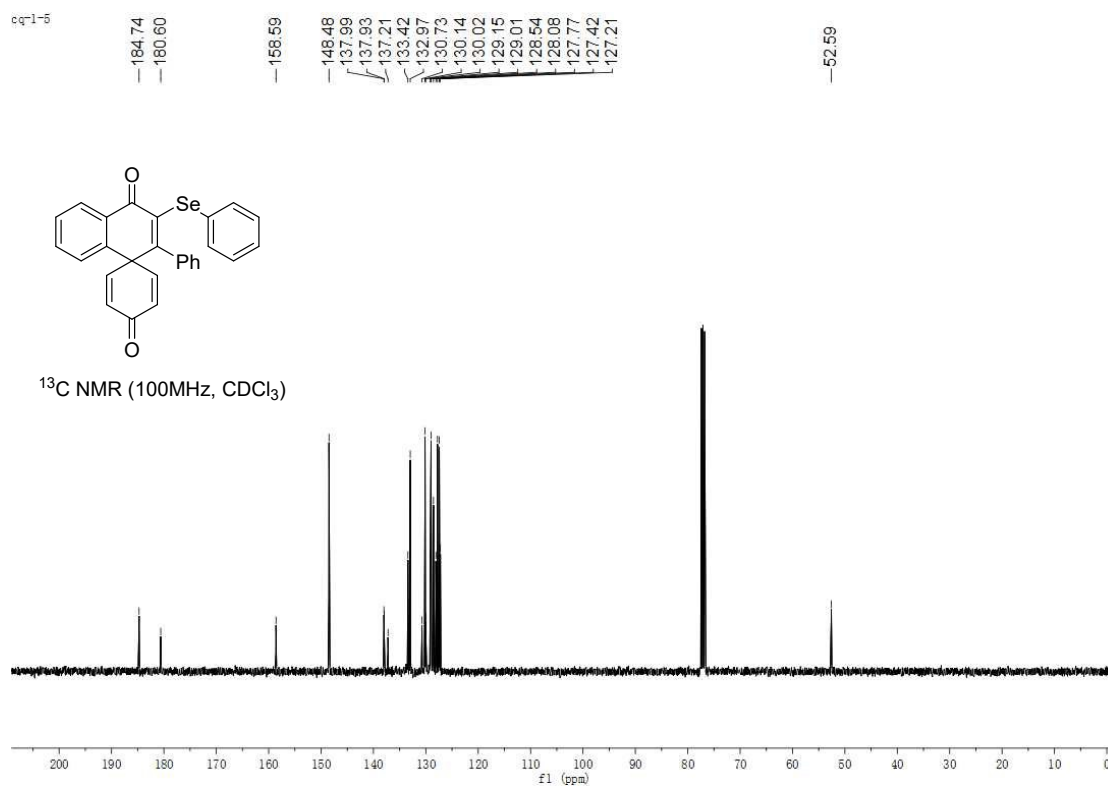


^{13}C NMR spectrum of **3aa**

eq-1-5

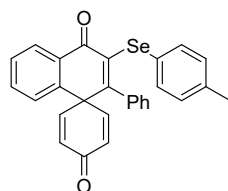


^{13}C NMR (100MHz, CDCl_3)

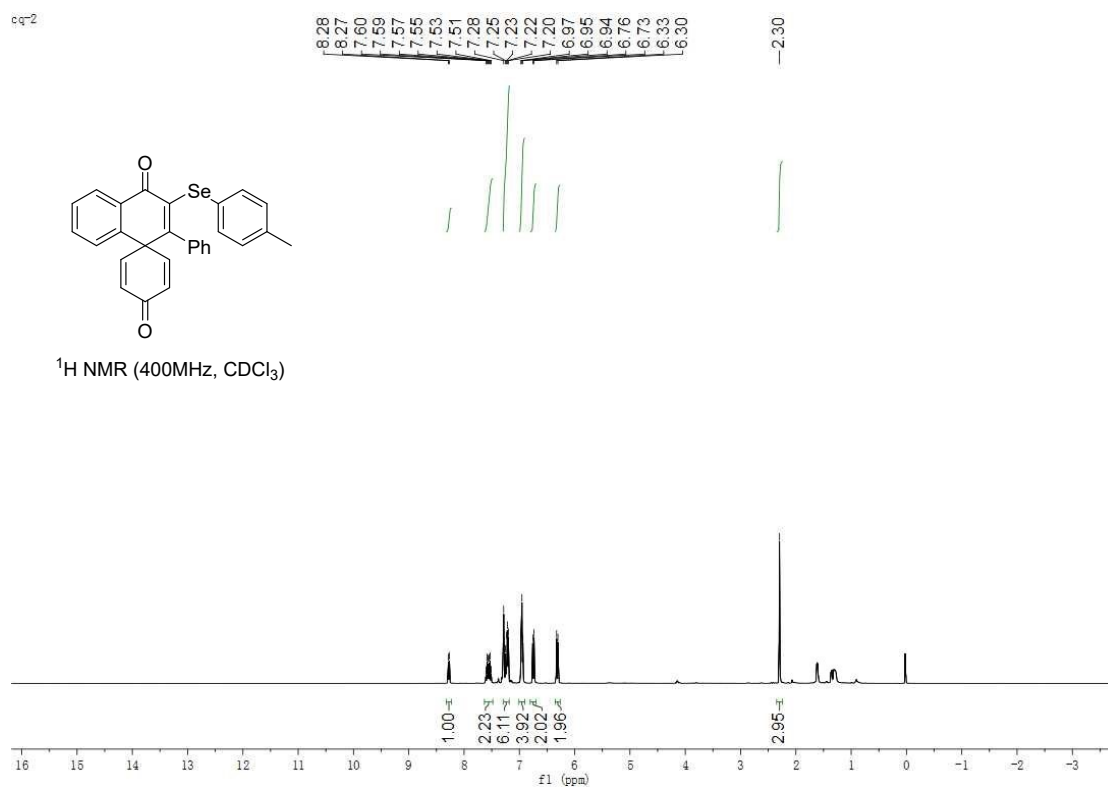


¹H NMR spectrum of **3ab**

cq-2

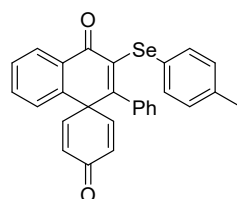


¹H NMR (400MHz, CDCl₃)

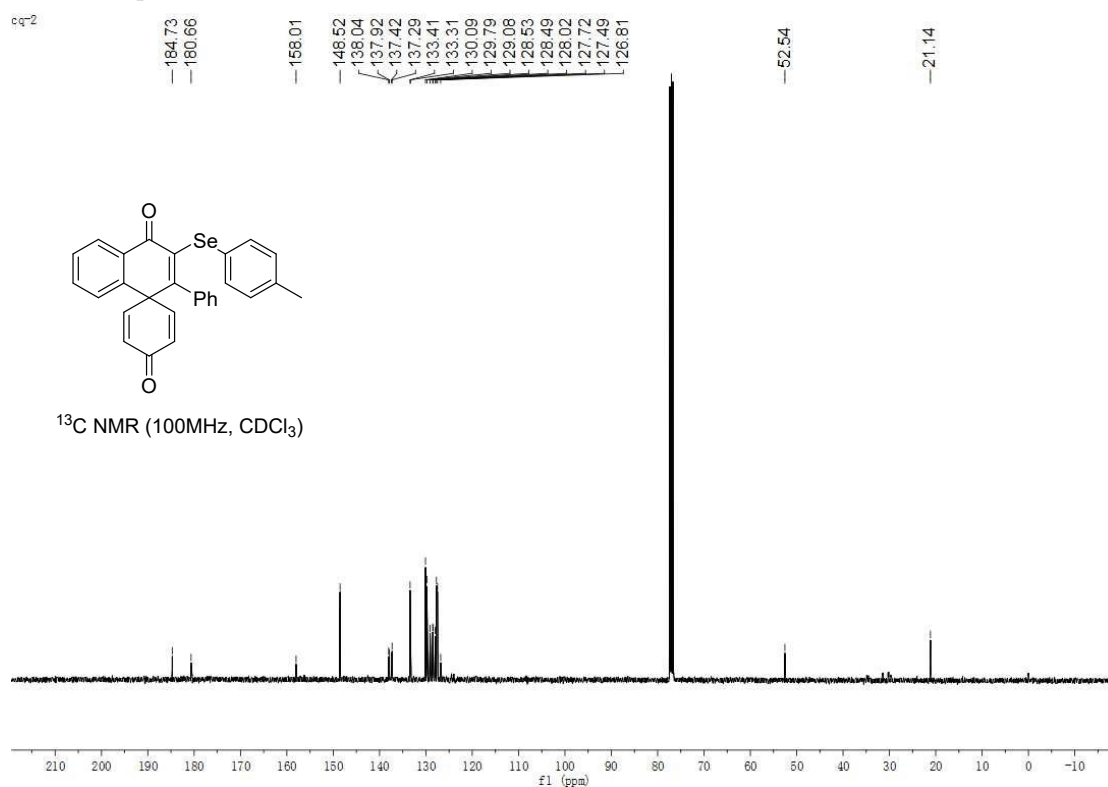


¹³C NMR spectrum of **3ab**

cq-2

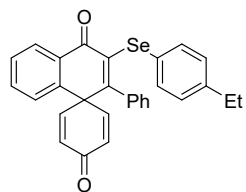


¹³C NMR (100MHz, CDCl₃)

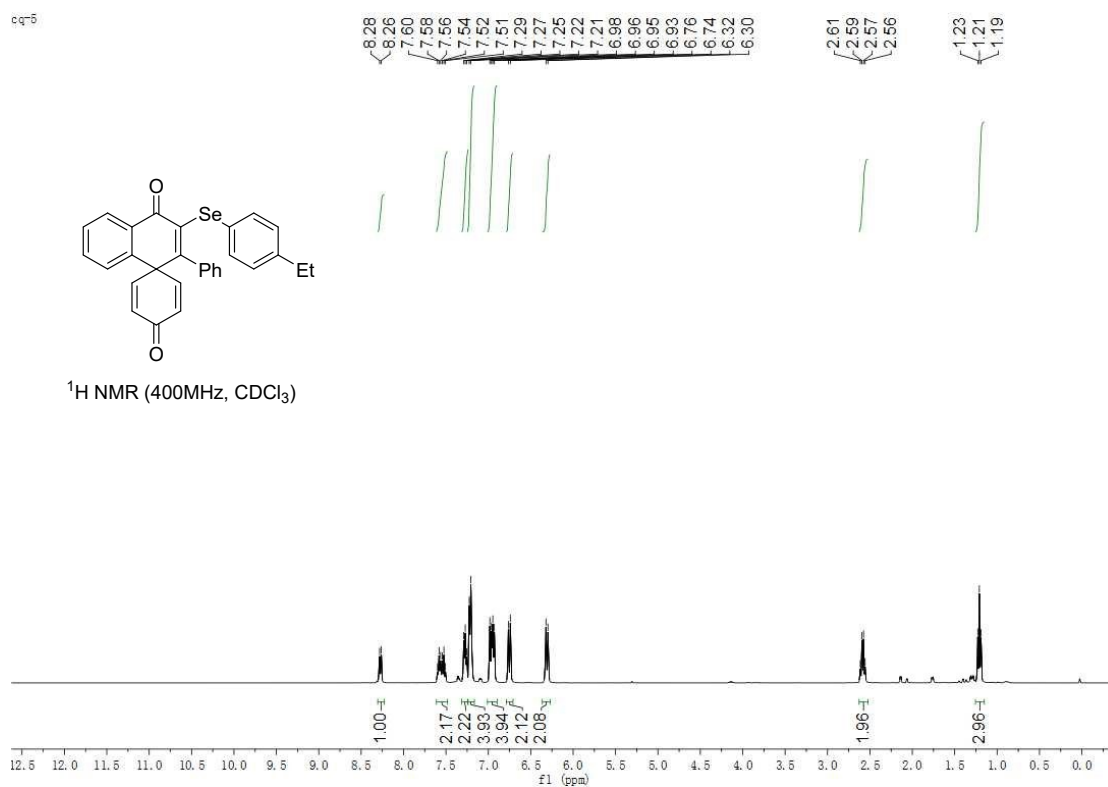


¹H NMR spectrum of **3ac**

ppm

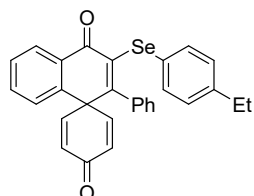


¹H NMR (400MHz, CDCl₃)

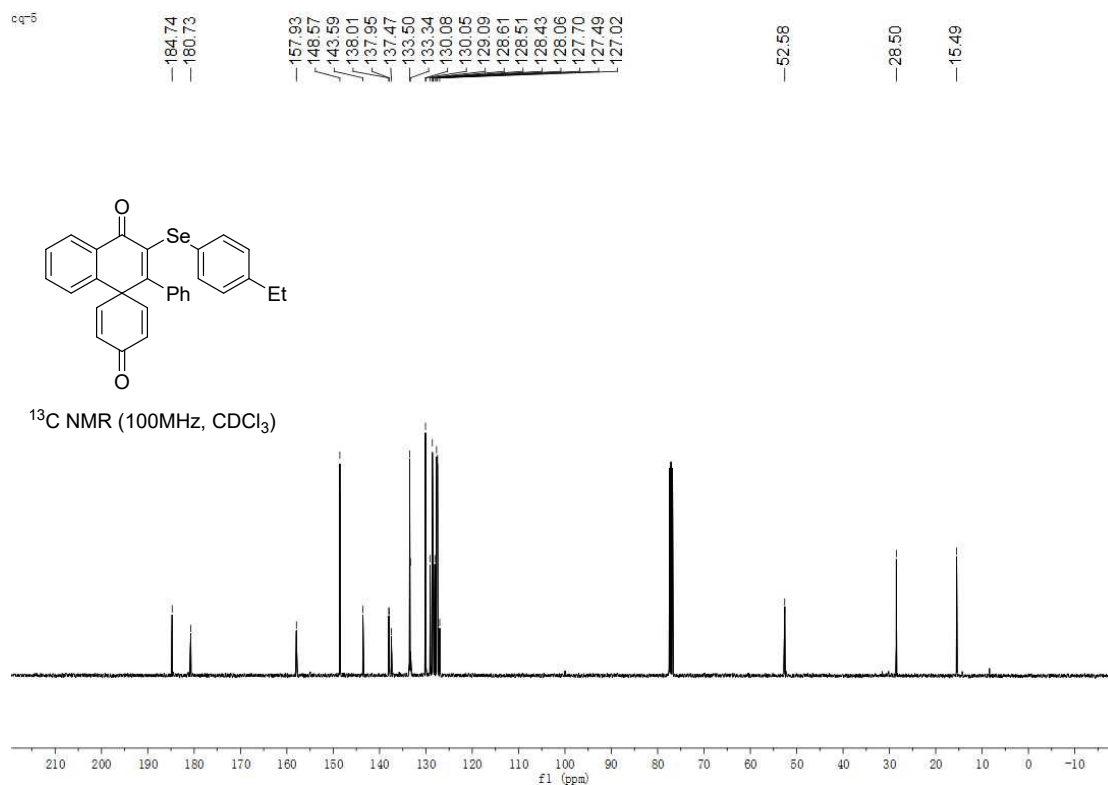


¹³C NMR spectrum of **3ac**

ppm

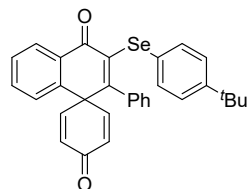


¹³C NMR (100MHz, CDCl₃)

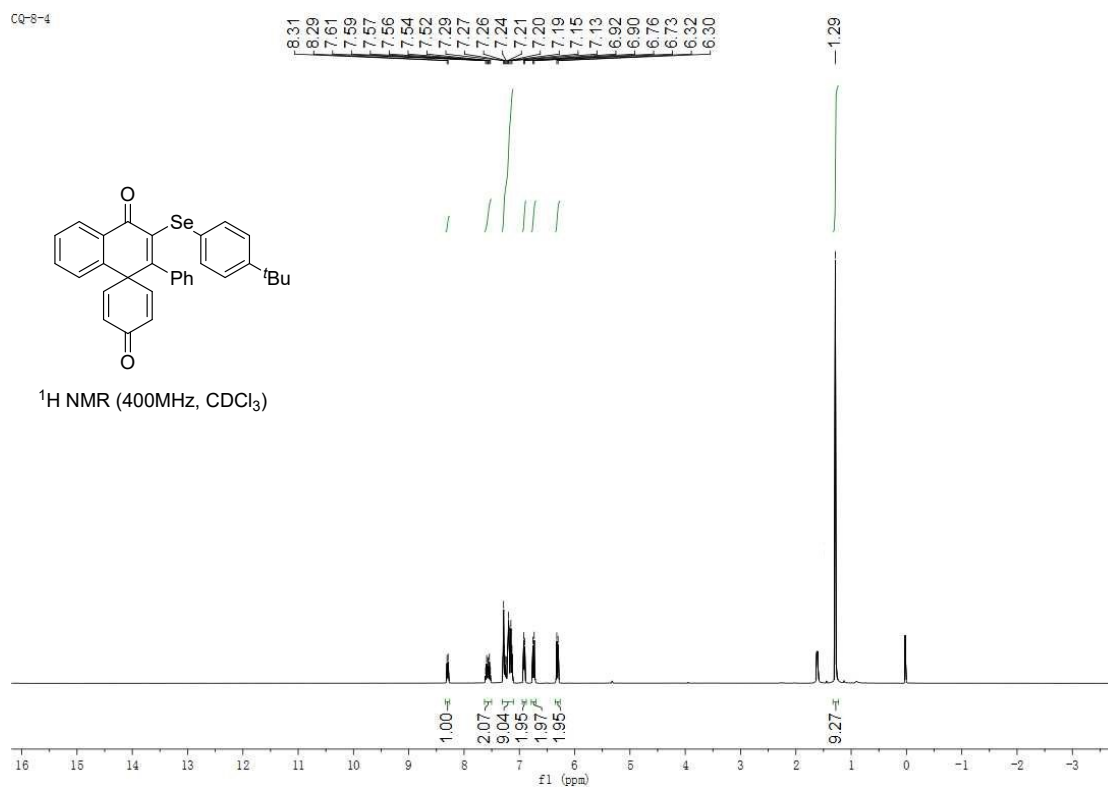


¹H NMR spectrum of **3ad**

CQ-8-4

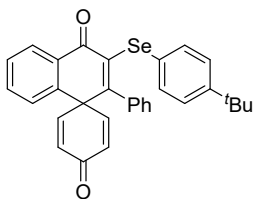


¹H NMR (400MHz, CDCl₃)

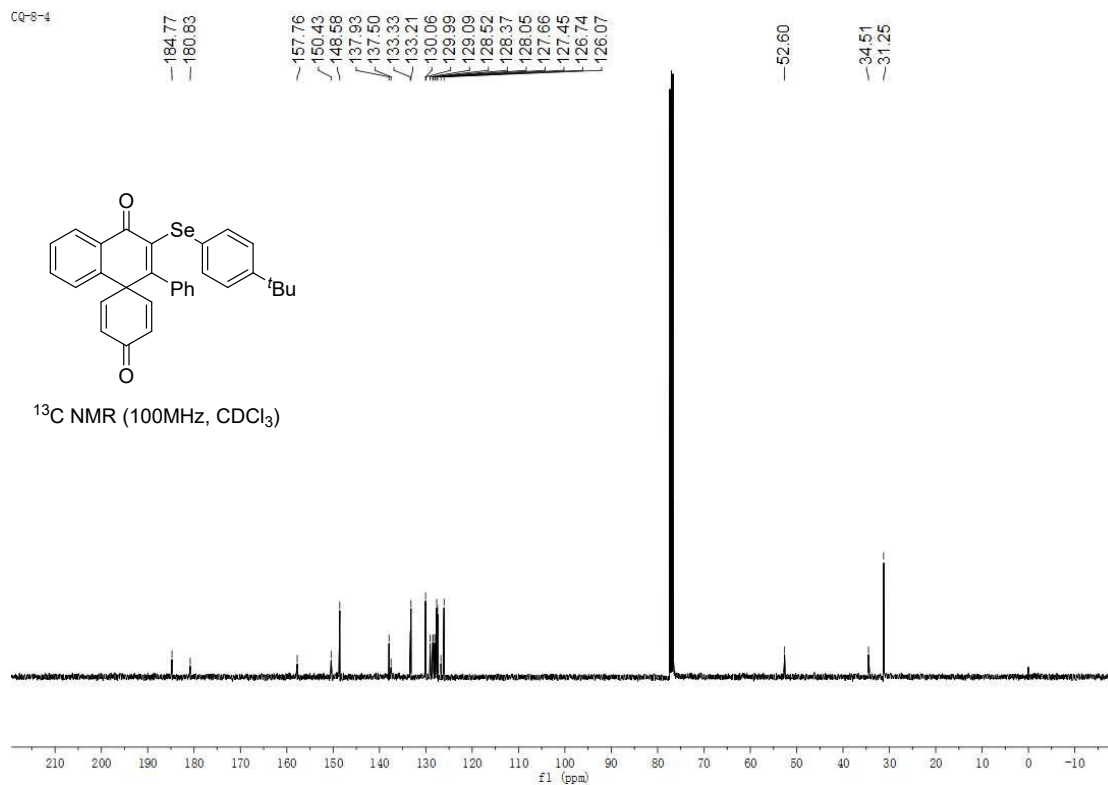


¹³C NMR spectrum of **3ad**

CQ-8-4

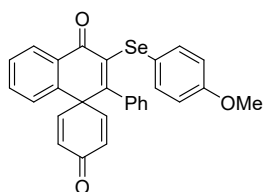


¹³C NMR (100MHz, CDCl₃)

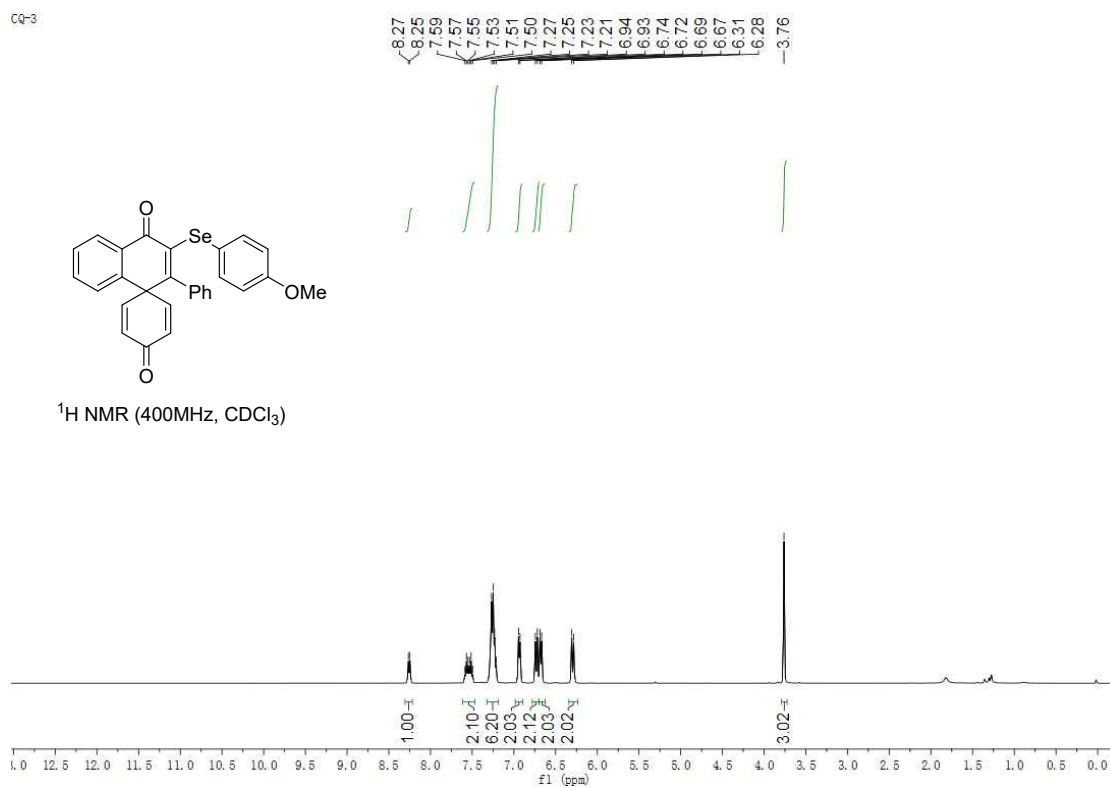


¹H NMR spectrum of **3ae**

CQ-3

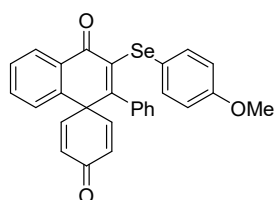


¹H NMR (400MHz, CDCl₃)

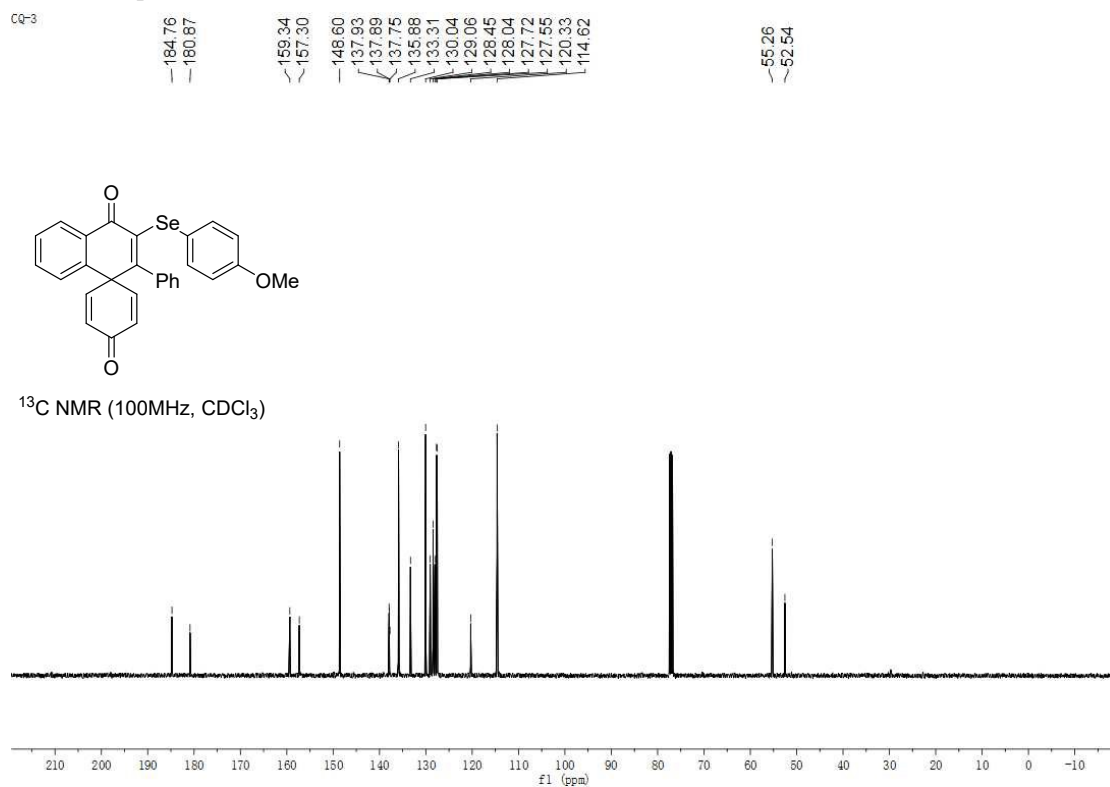


¹³C NMR spectrum of **3ae**

CQ-3

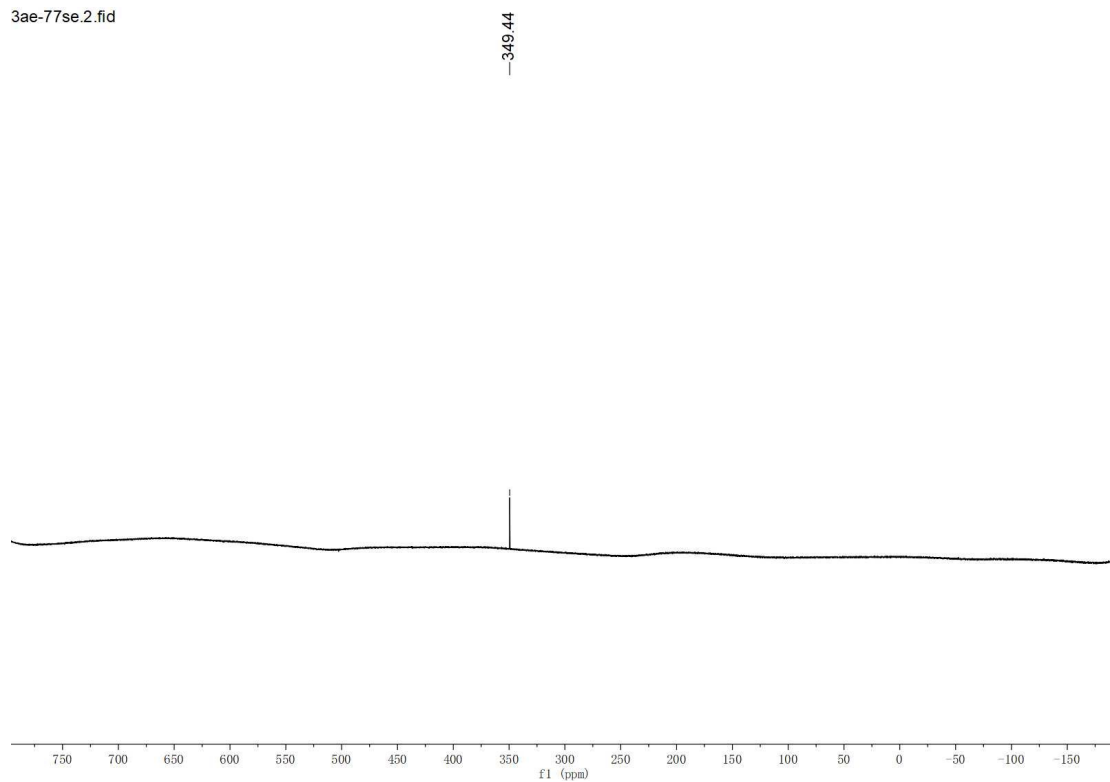


¹³C NMR (100MHz, CDCl₃)



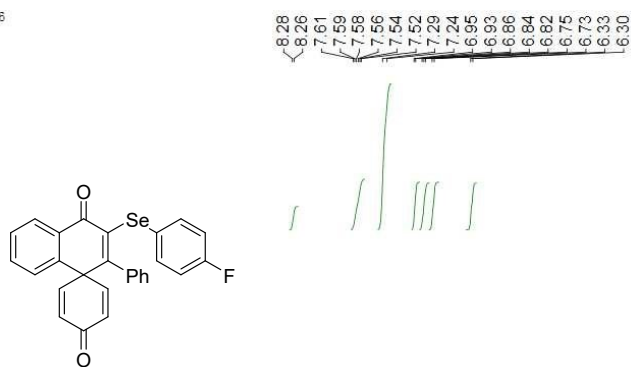
⁷⁷Se NMR spectrum of **3ae**

3ae-77se.2.fid

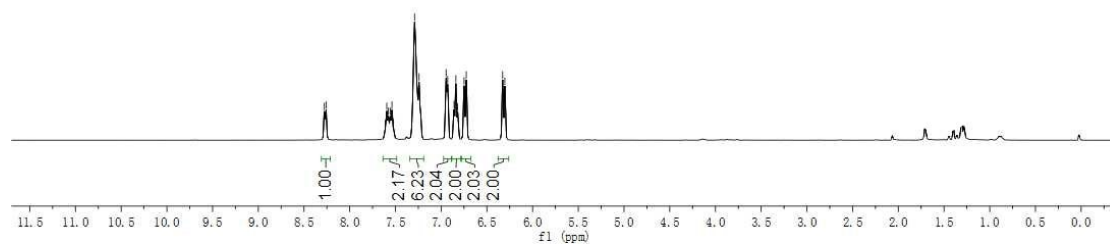


¹H NMR spectrum of **3af**

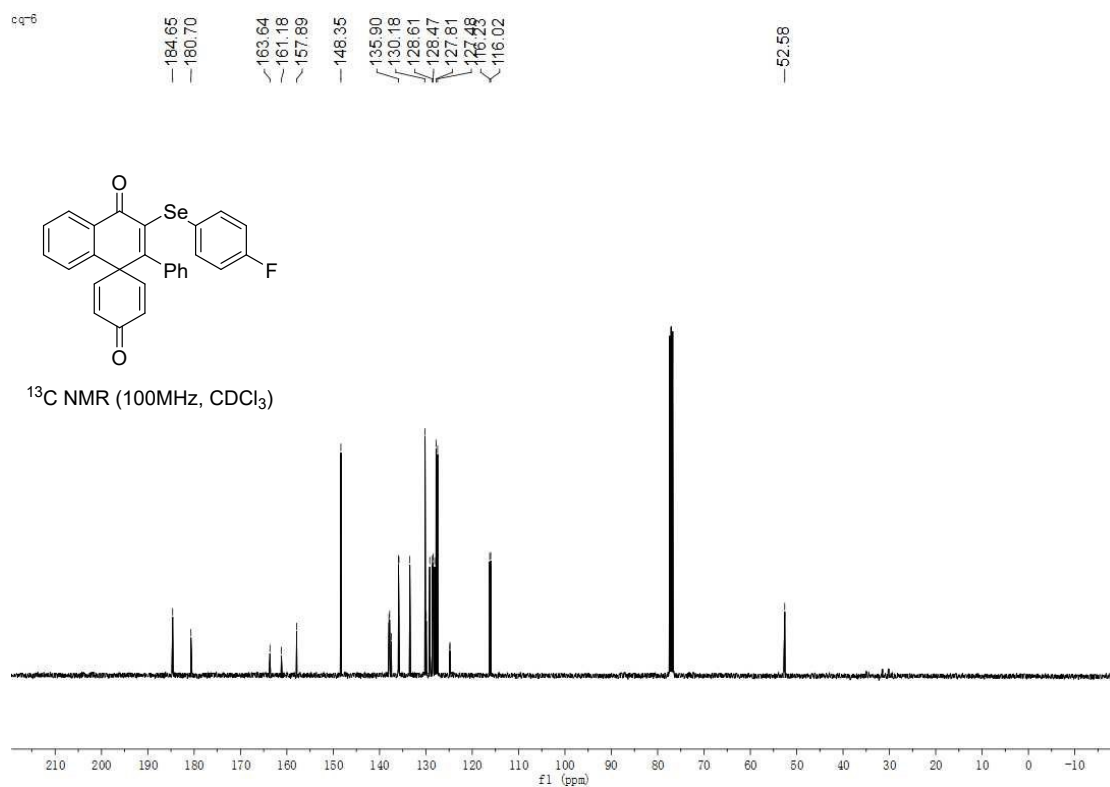
cq-b



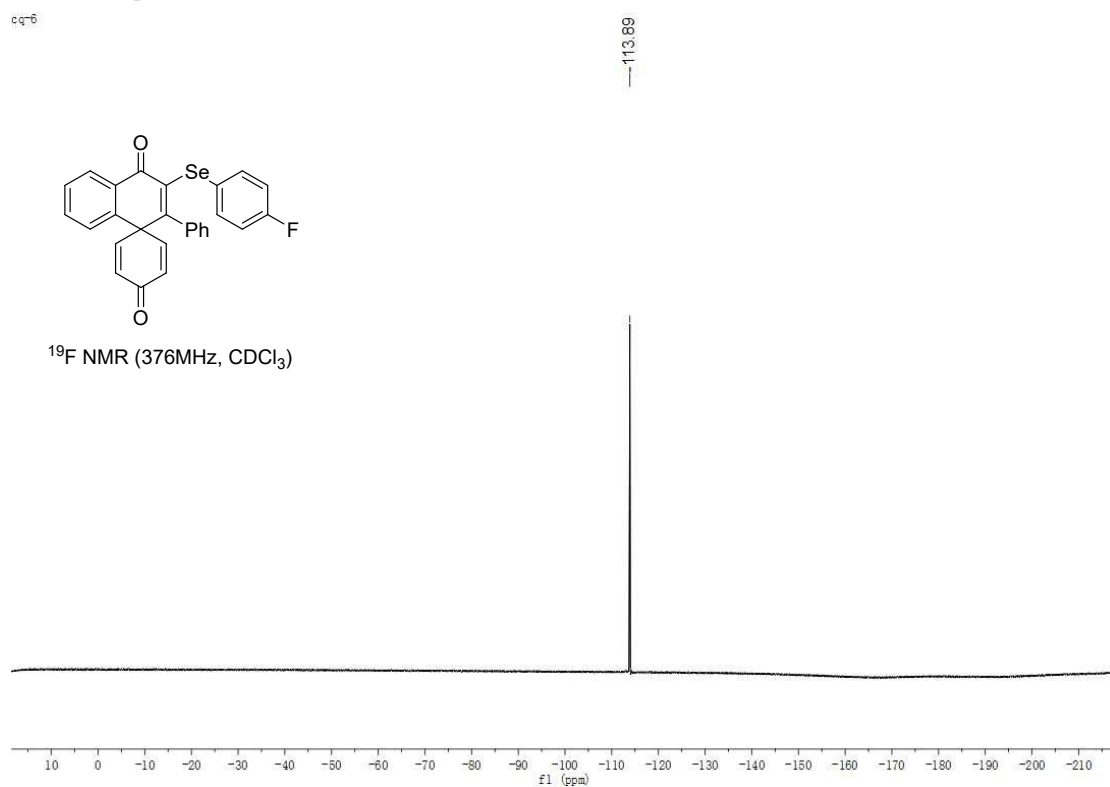
¹H NMR (400MHz, CDCl₃)



¹³C NMR spectrum of **3af**

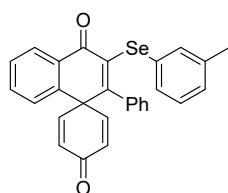


¹⁹F NMR spectrum of **3af**

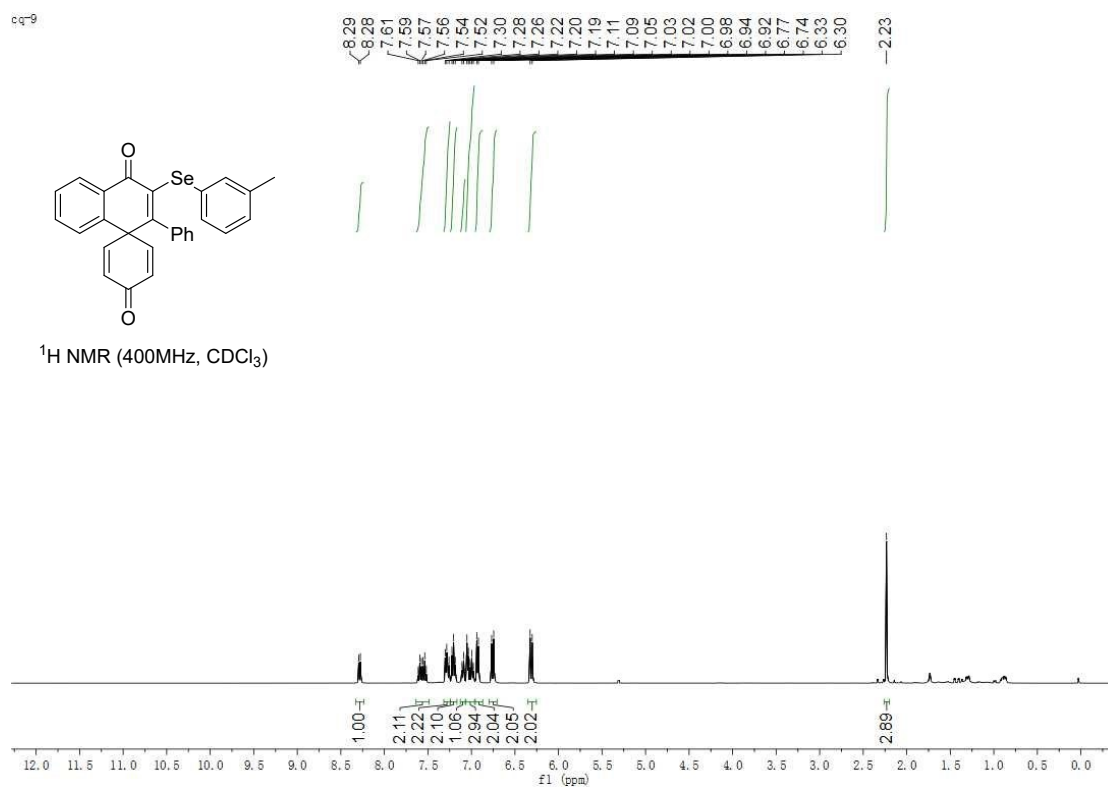


¹H NMR spectrum of **3ag**

cq-g

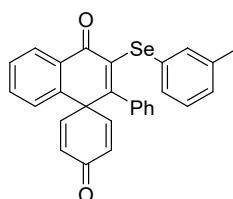


¹H NMR (400MHz, CDCl₃)

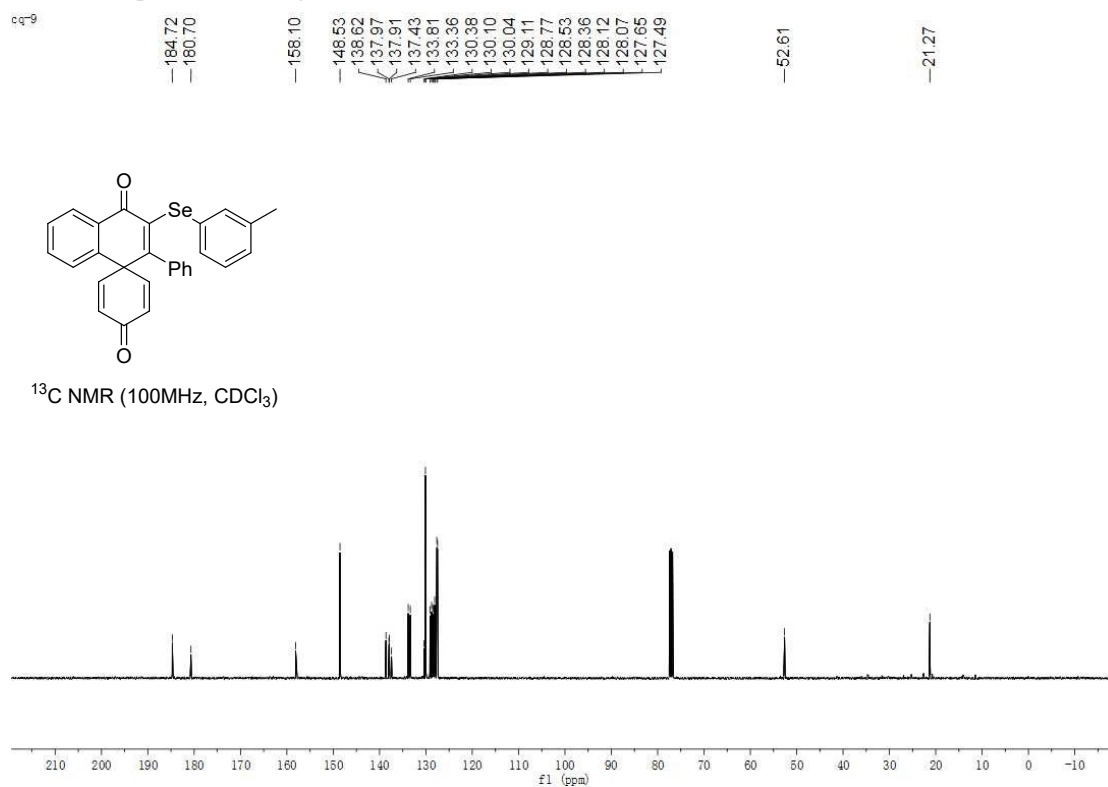


¹³C NMR spectrum of **3ag**

cq-g

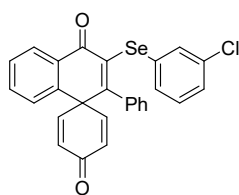


¹³C NMR (100MHz, CDCl₃)

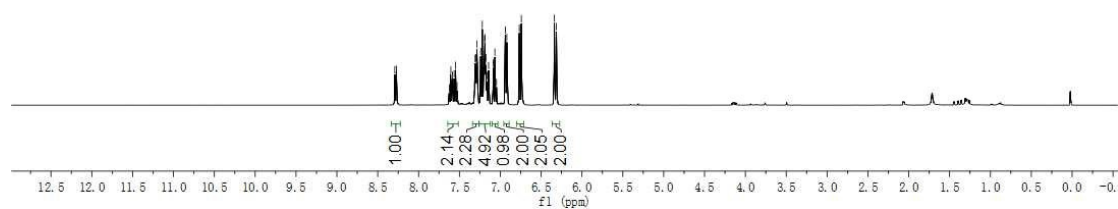
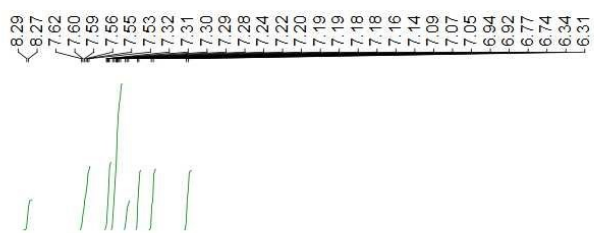


¹H NMR spectrum of **3ah**

cg-11

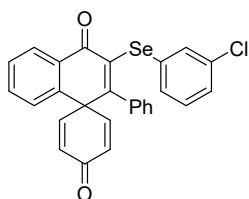


¹H NMR (400MHz, CDCl₃)

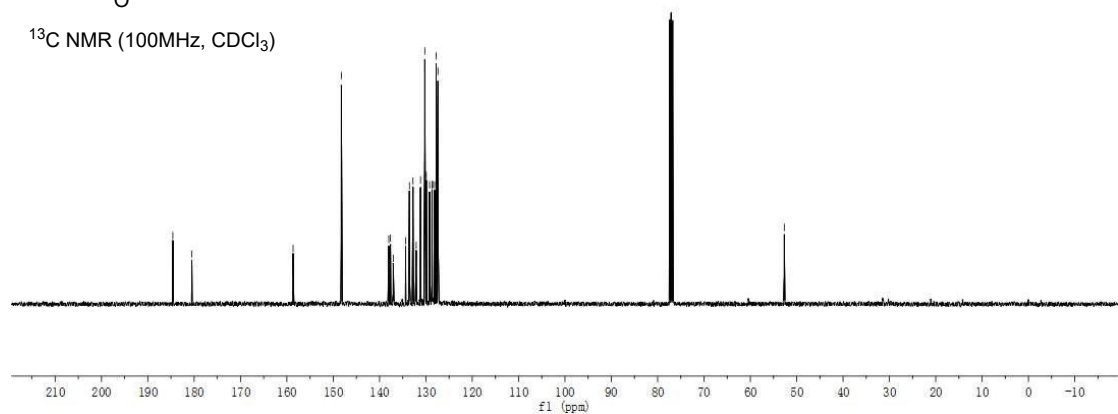


¹³C NMR spectrum of **3ah**

cg-11

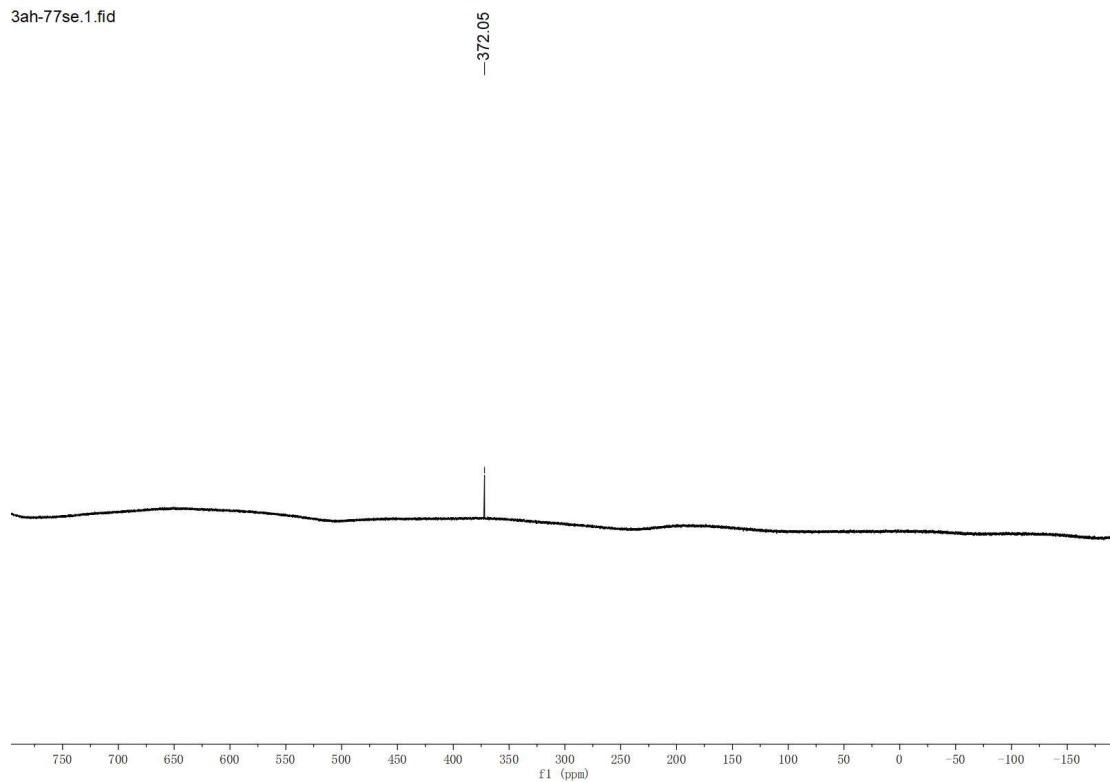


¹³C NMR (100MHz, CDCl₃)



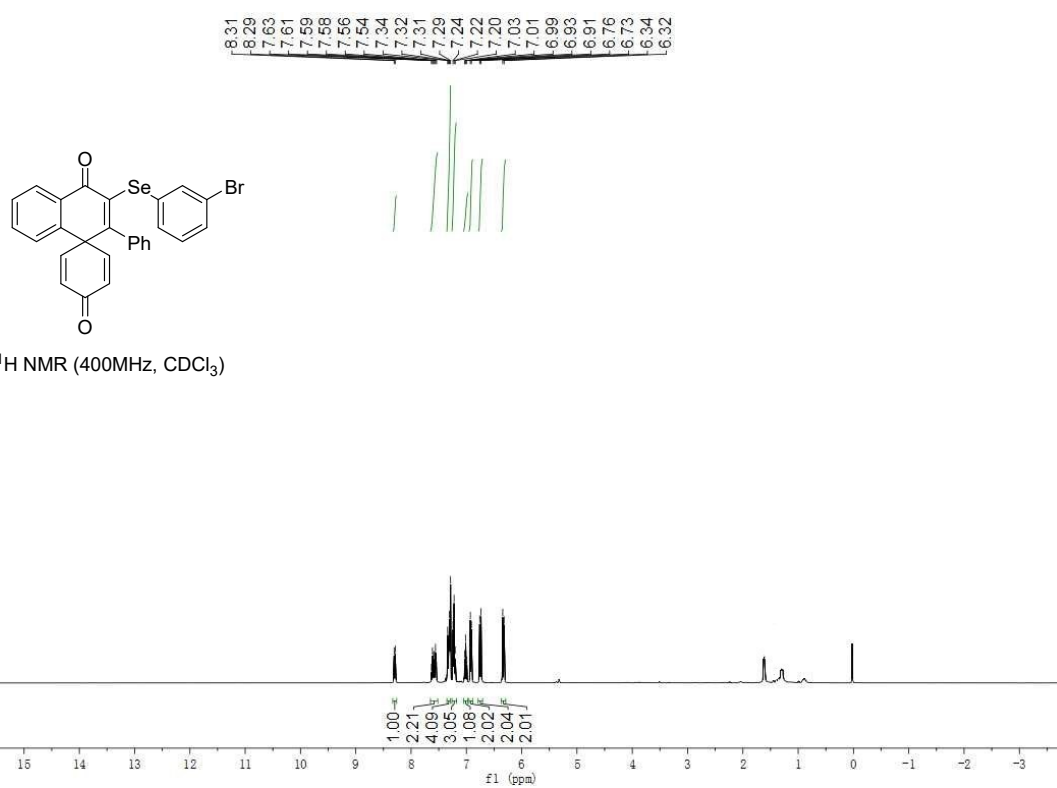
⁷⁷Se NMR spectrum of **3ah**

3ah-77se.1.fid

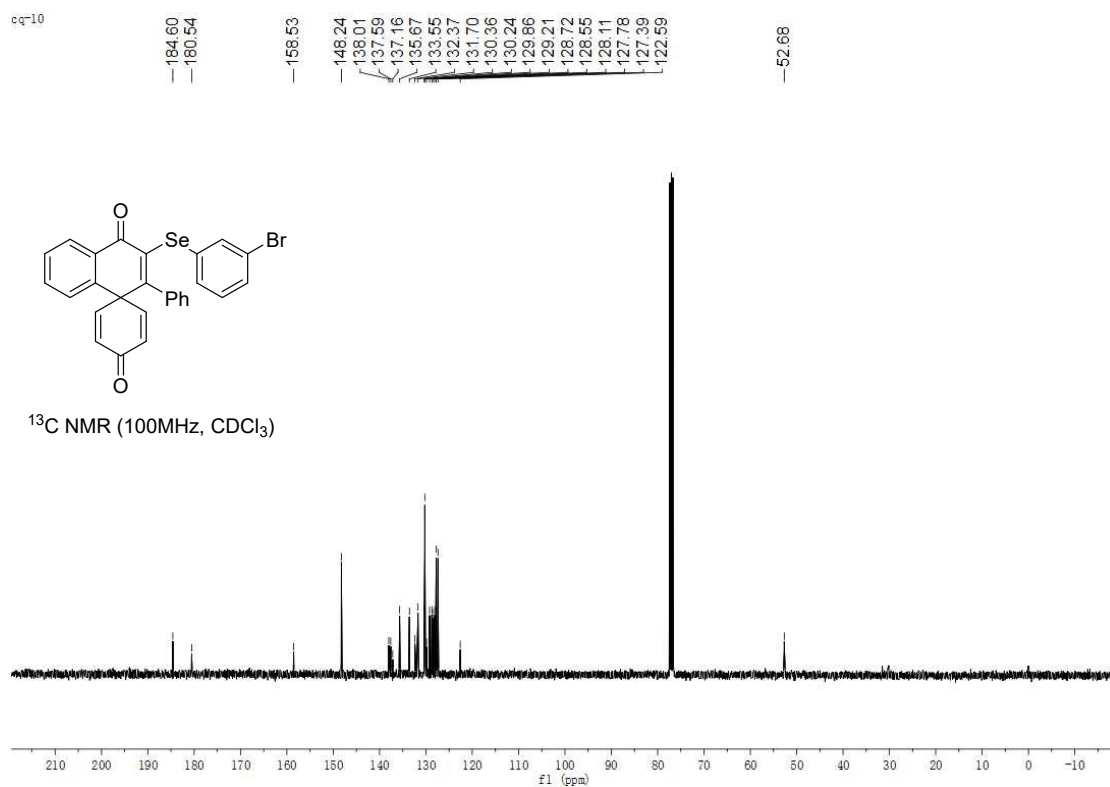


¹H NMR spectrum of **3ai**

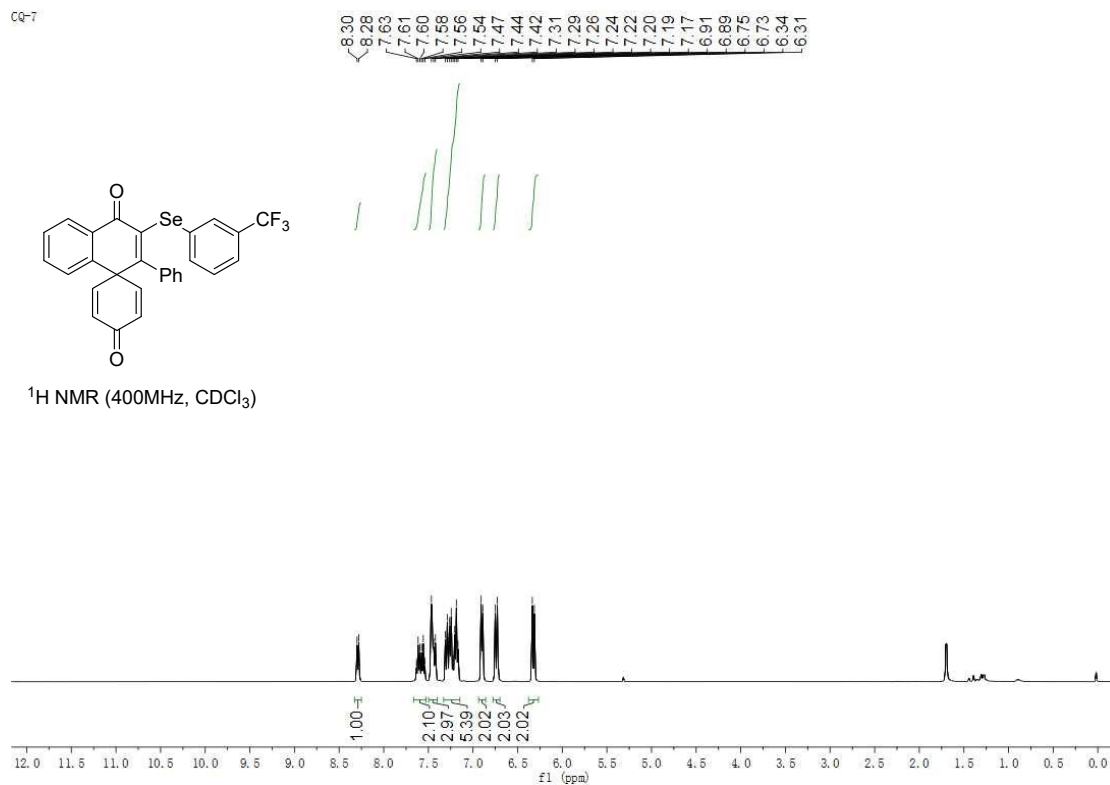
sq-10



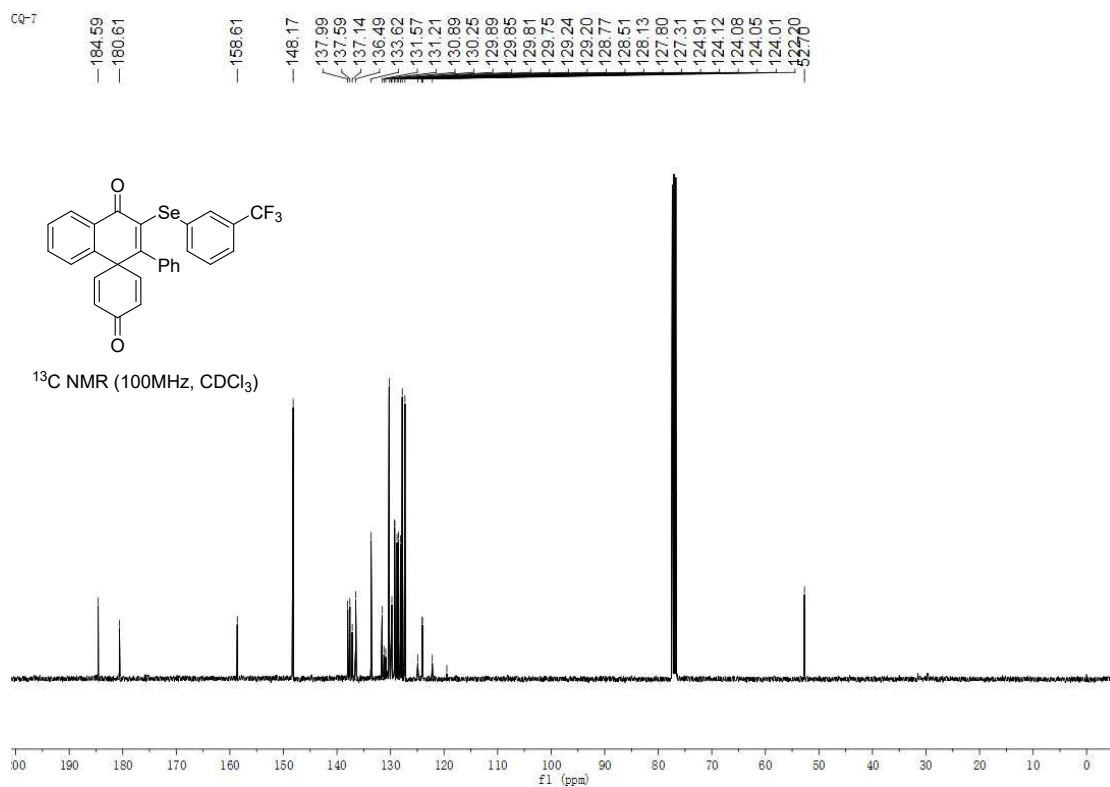
¹³C NMR spectrum of **3ai**



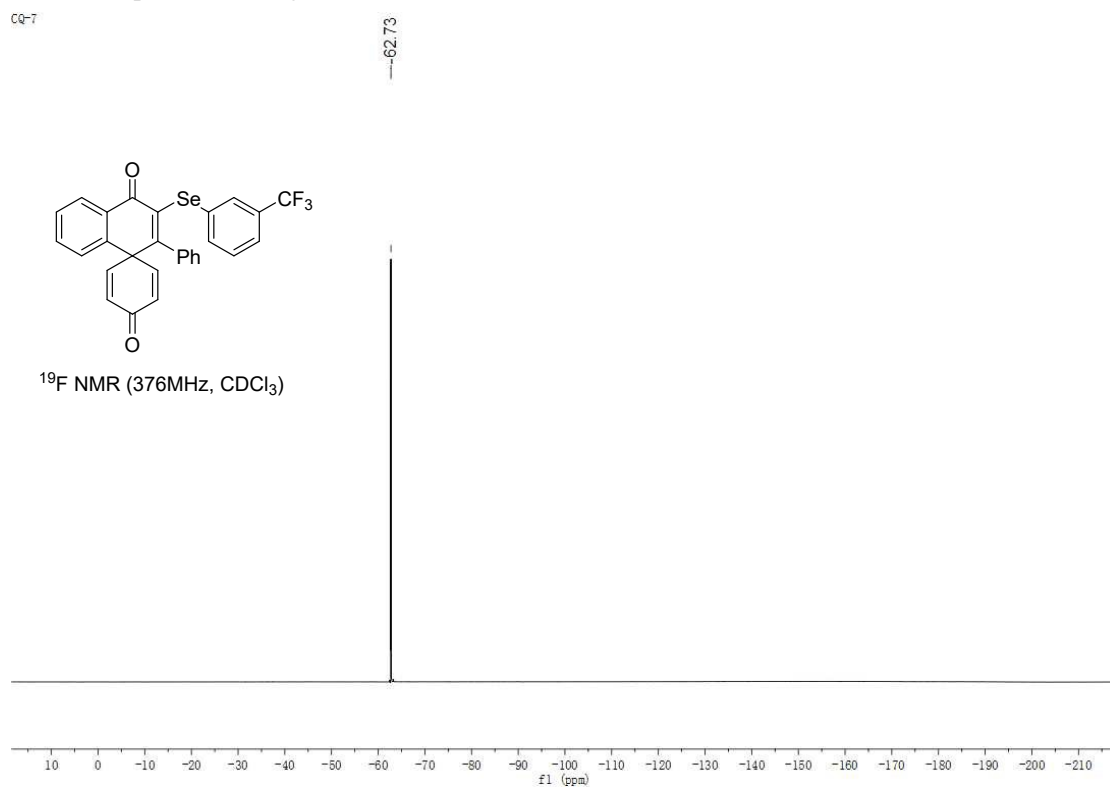
¹H NMR spectrum of **3aj**



¹³C NMR spectrum of **3aj**

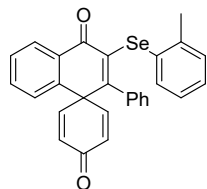


¹⁹F NMR spectrum of **3aj**

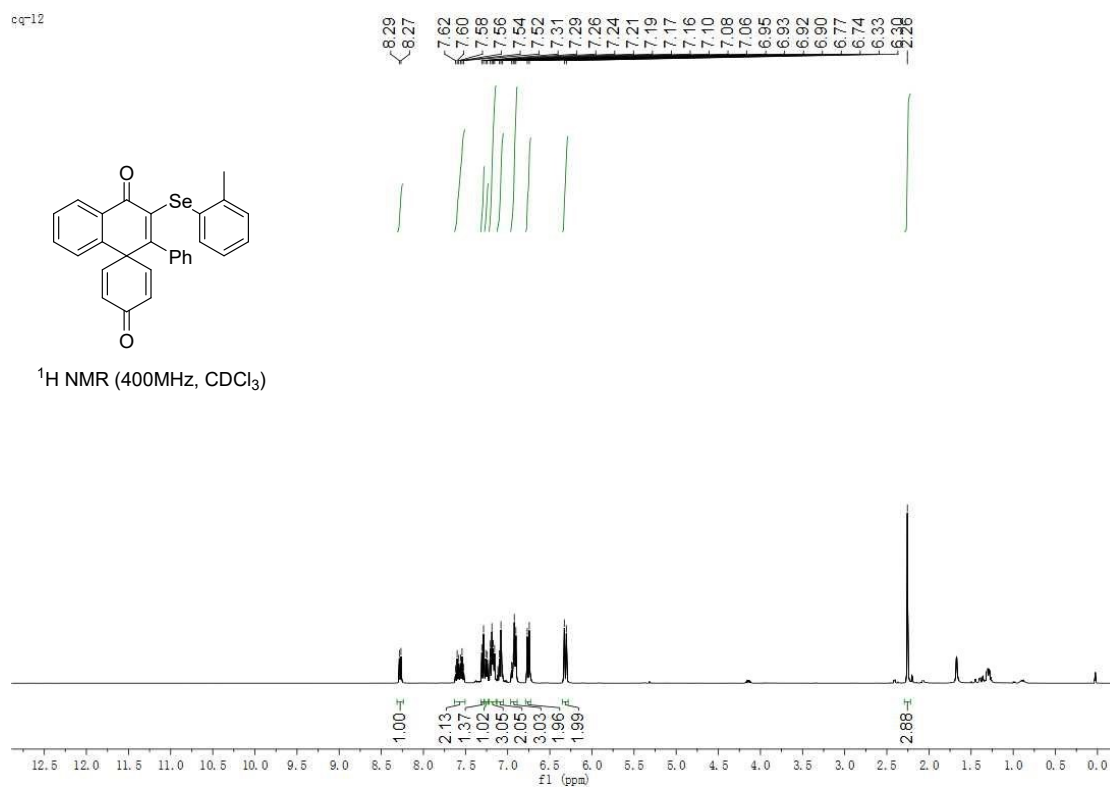


¹H NMR spectrum of **3ak**

cg-12

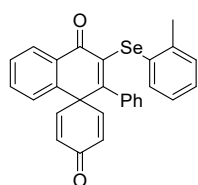


¹H NMR (400MHz, CDCl₃)

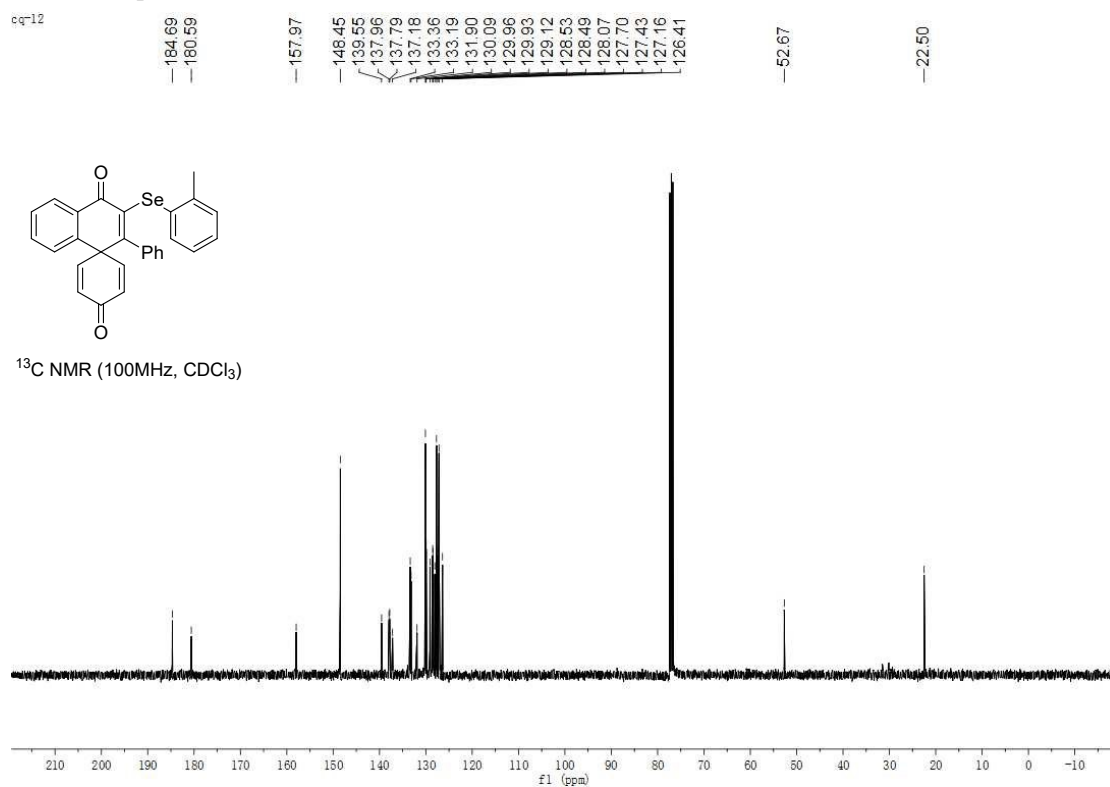


¹³C NMR spectrum of **3ak**

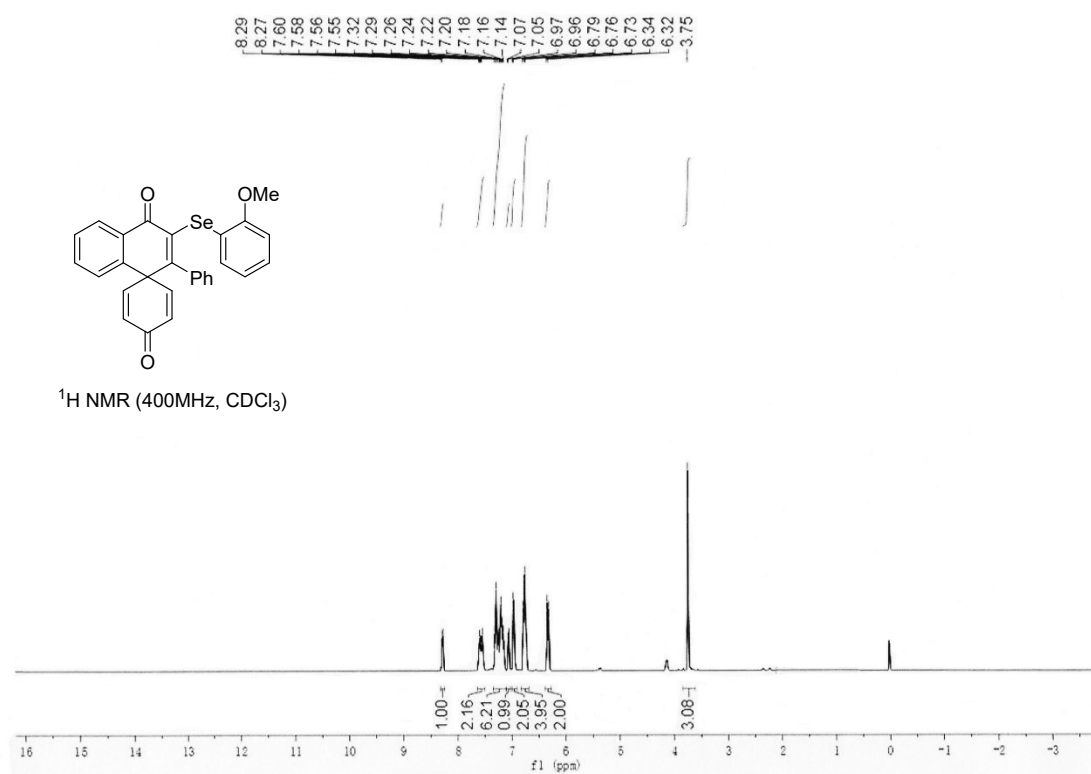
cg-12



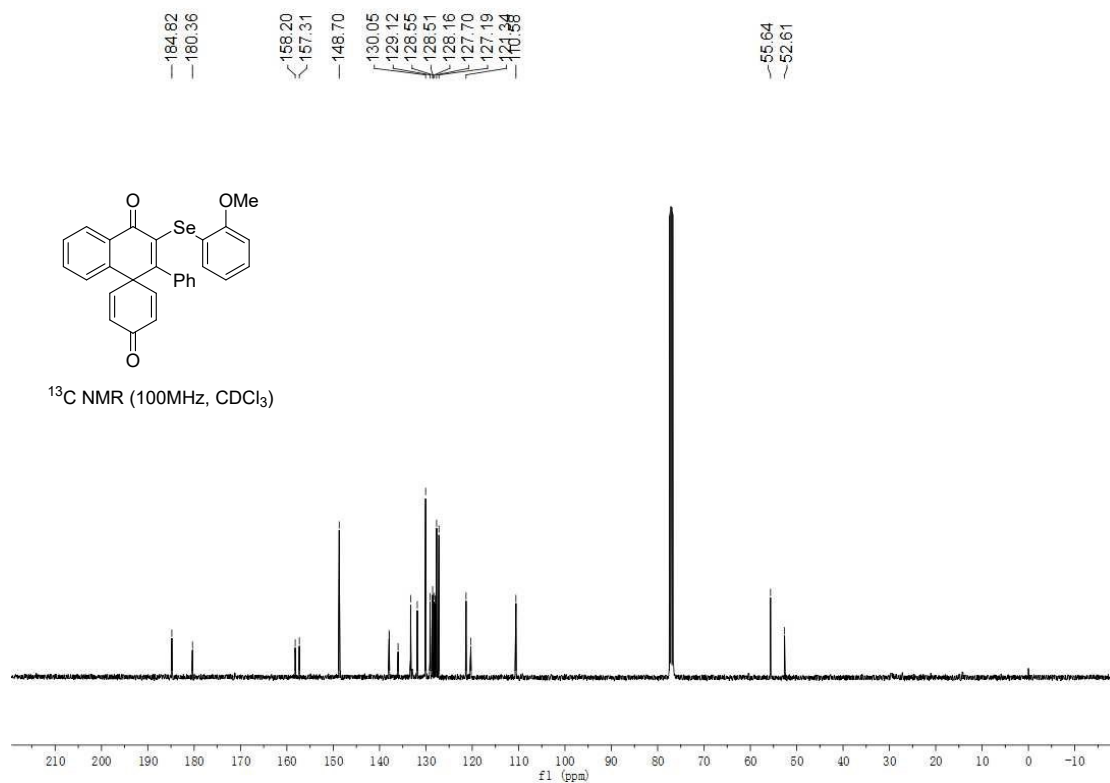
¹³C NMR (100MHz, CDCl₃)



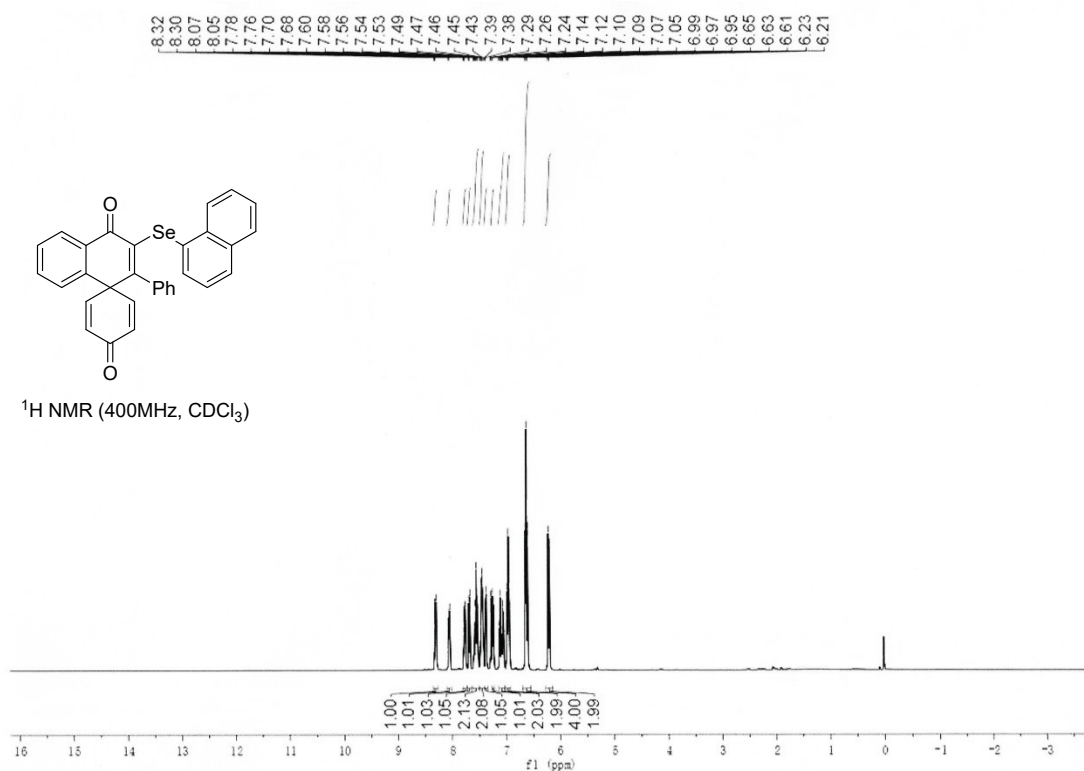
¹H NMR spectrum of **3al**



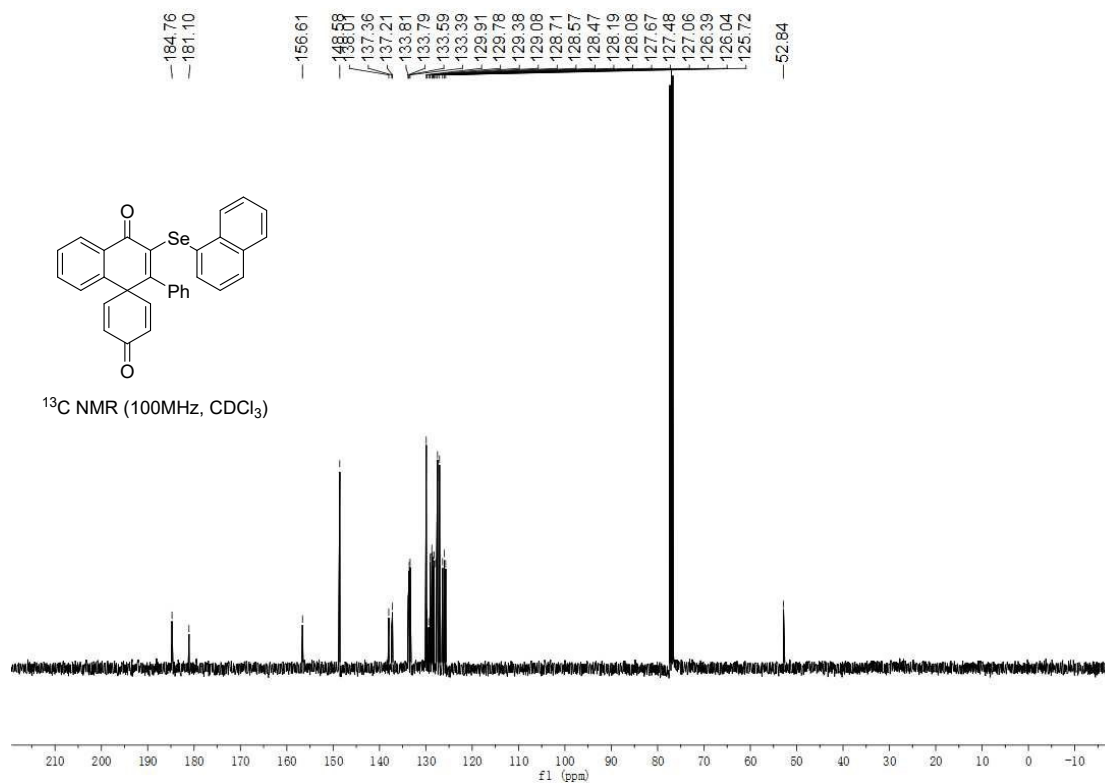
¹³C NMR spectrum of **3al**



¹H NMR spectrum of **3am**

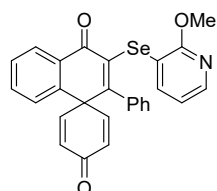


¹³C NMR spectrum of **3am**

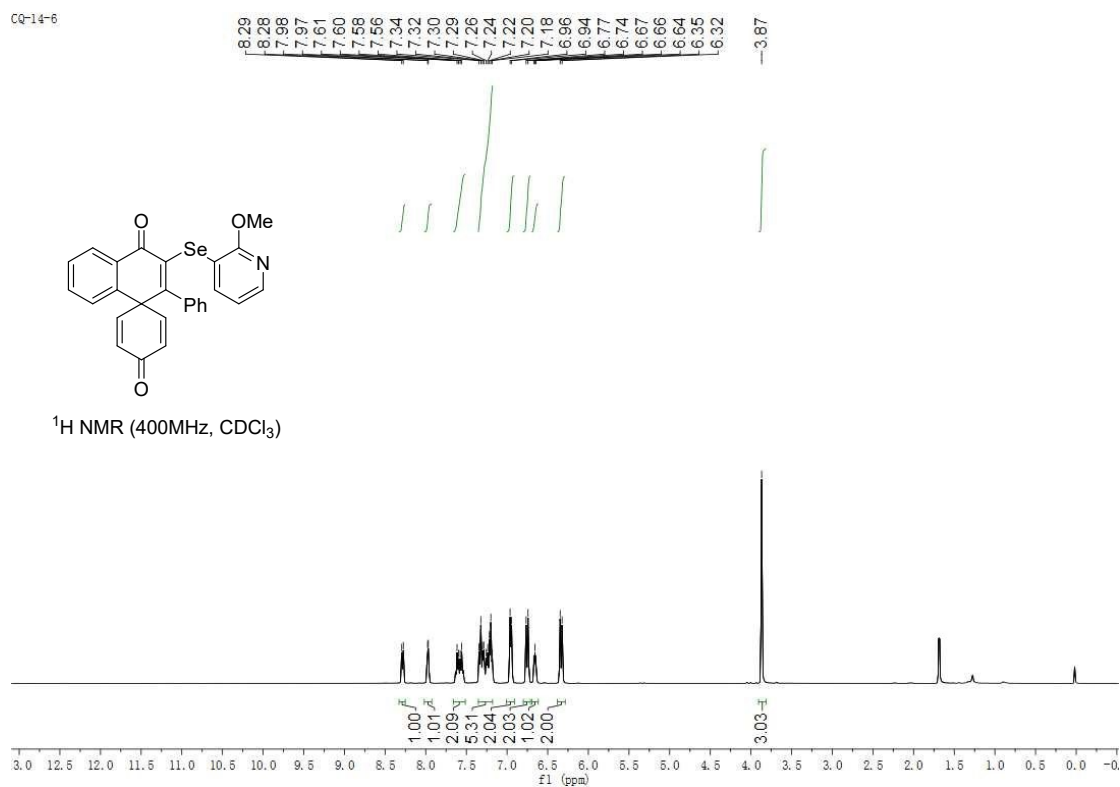


¹H NMR spectrum of **3an**

CQ-14-6

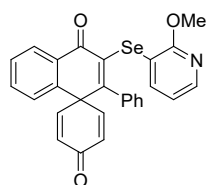


¹H NMR (400MHz, CDCl₃)

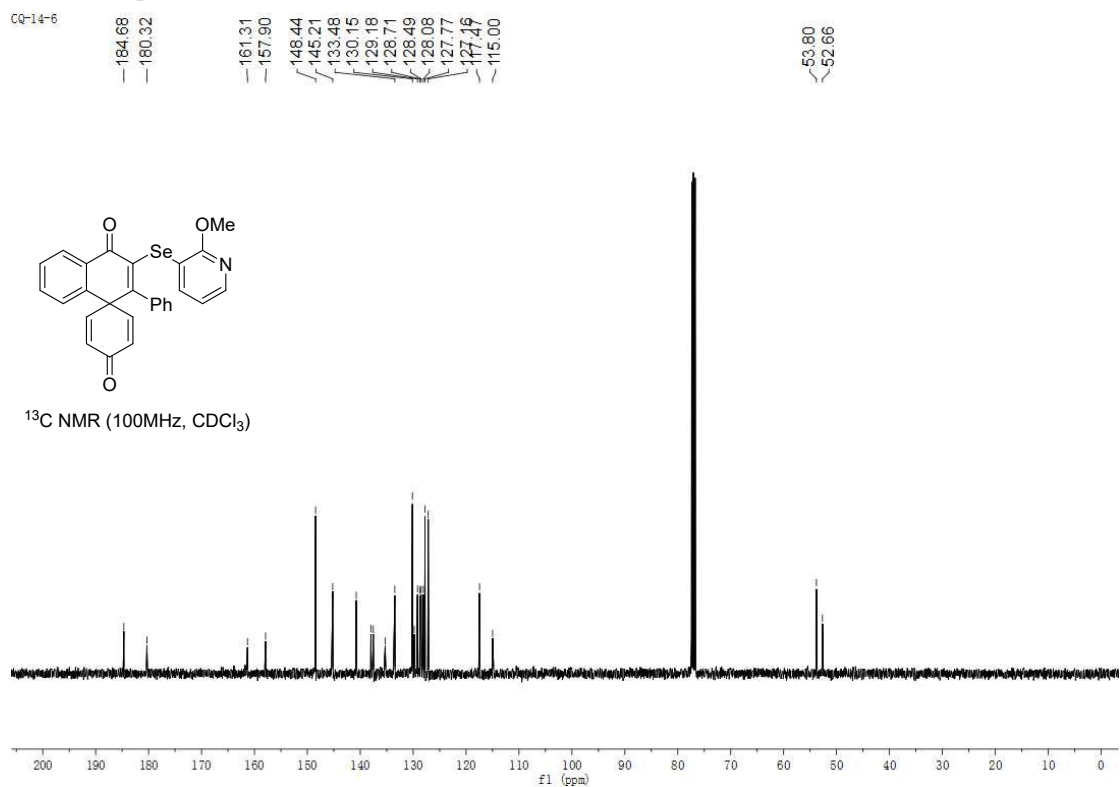


¹³C NMR spectrum of **3an**

CQ-14-6

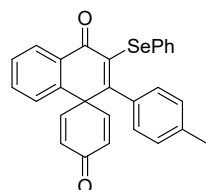


¹³C NMR (100MHz, CDCl₃)

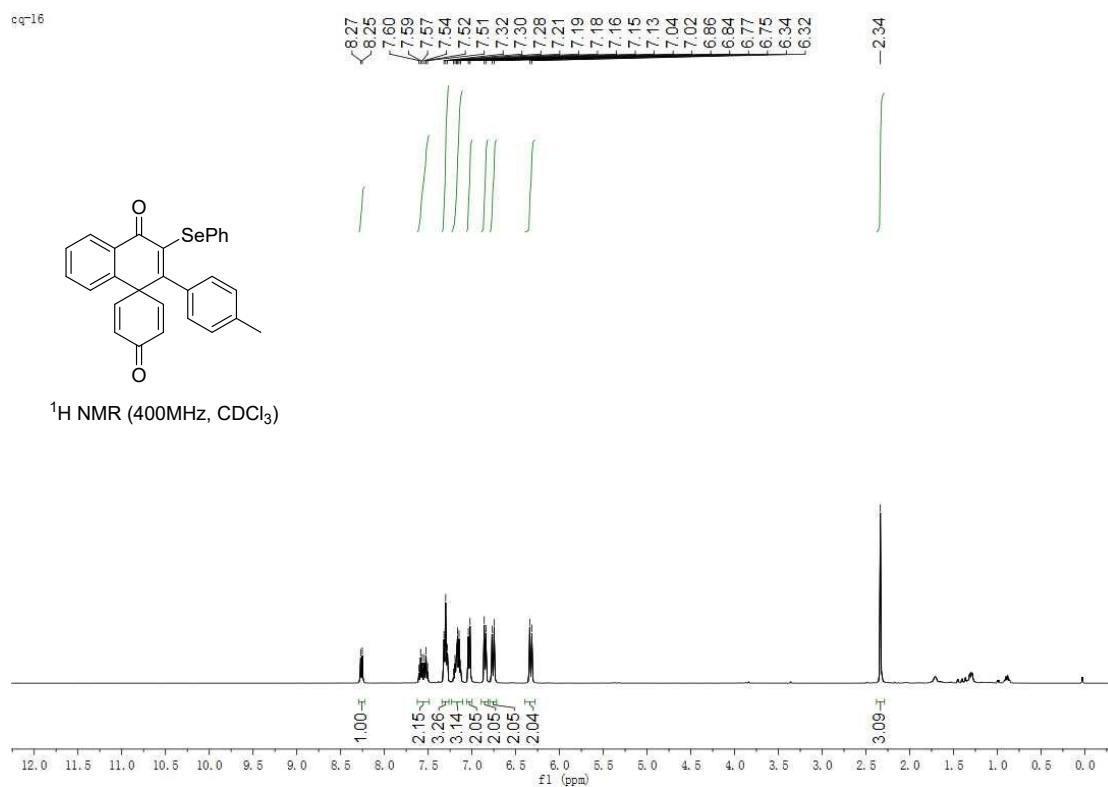


¹H NMR spectrum of **3ba**

cq-16

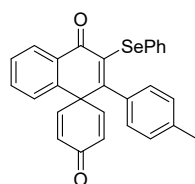


¹H NMR (400MHz, CDCl₃)

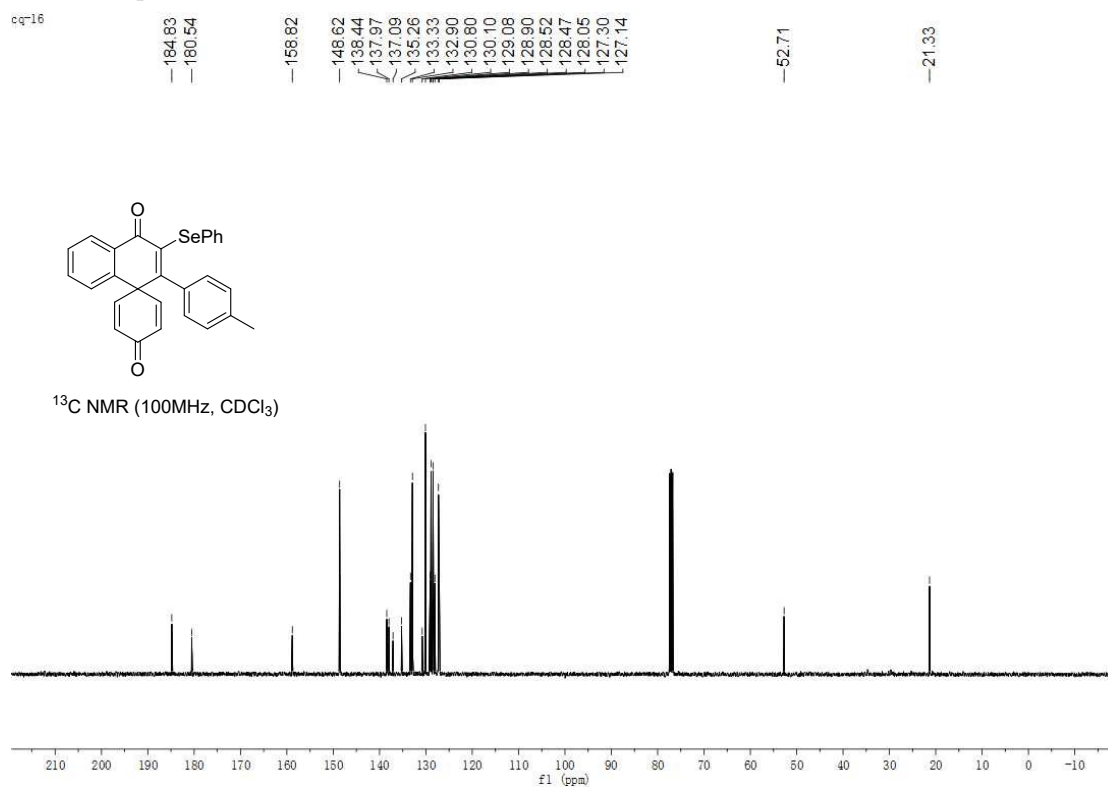


¹³C NMR spectrum of **3ba**

cq-16

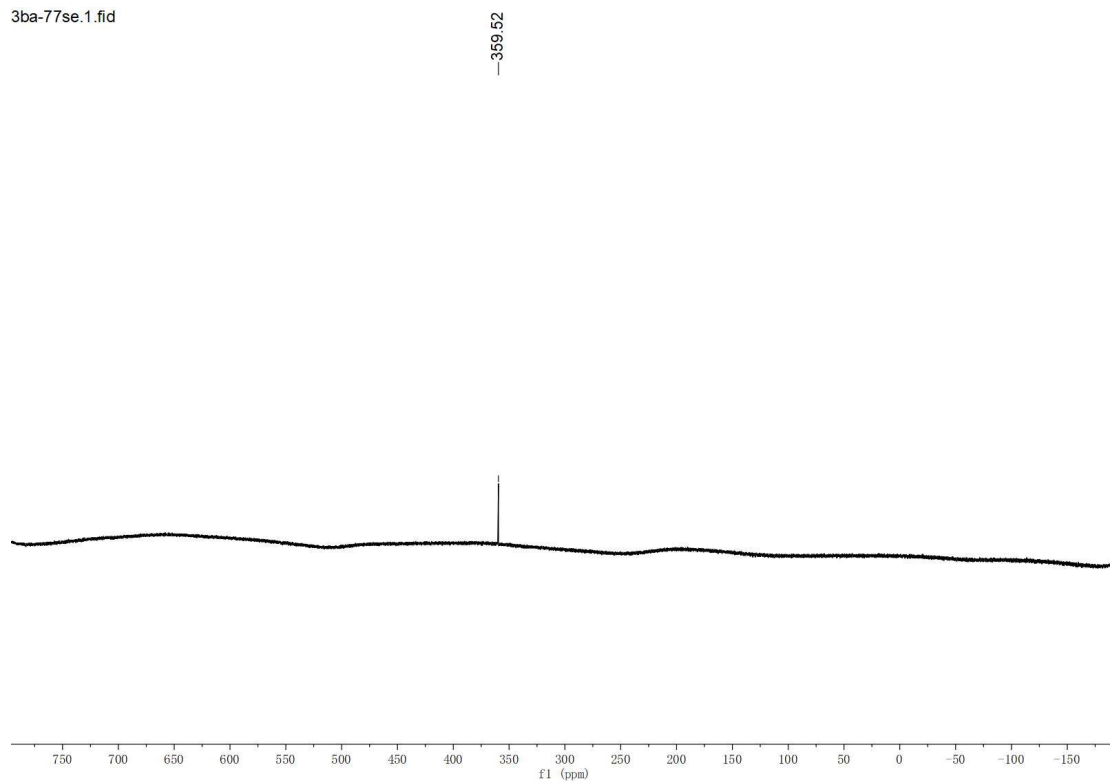


¹³C NMR (100MHz, CDCl₃)



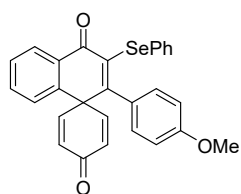
⁷⁷Se NMR spectrum of **3ba**

3ba-77se.1.fid

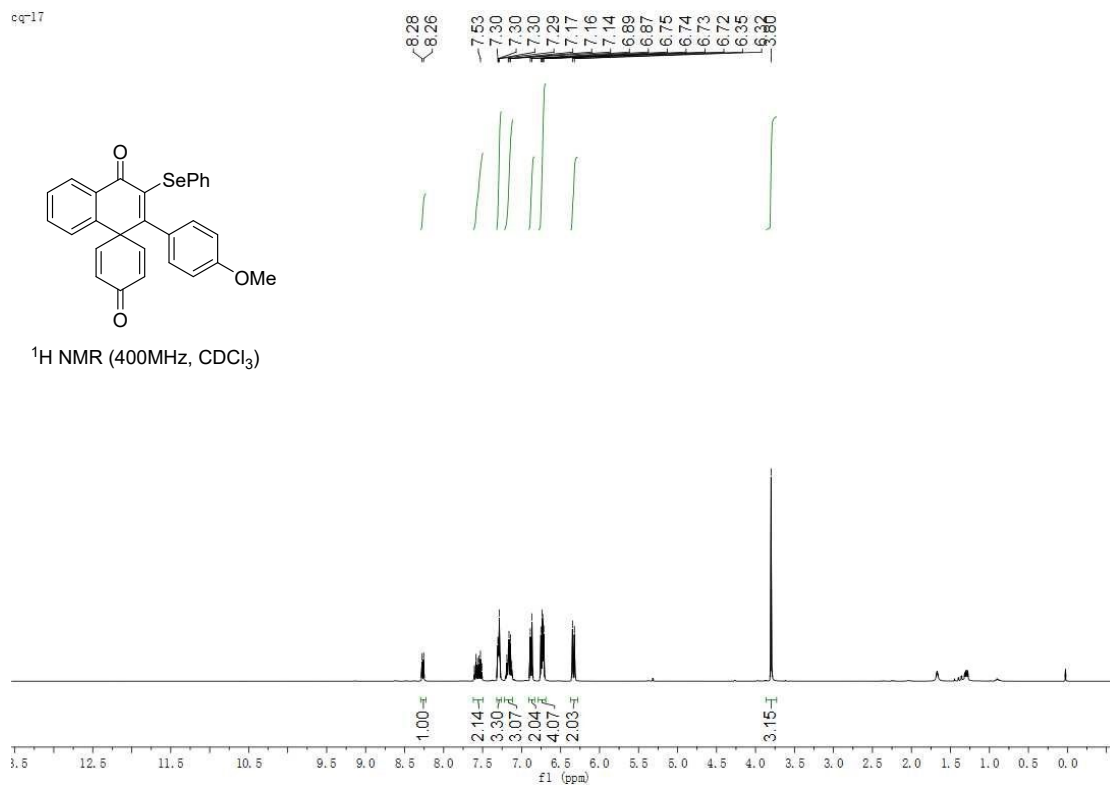


¹H NMR spectrum of **3ca**

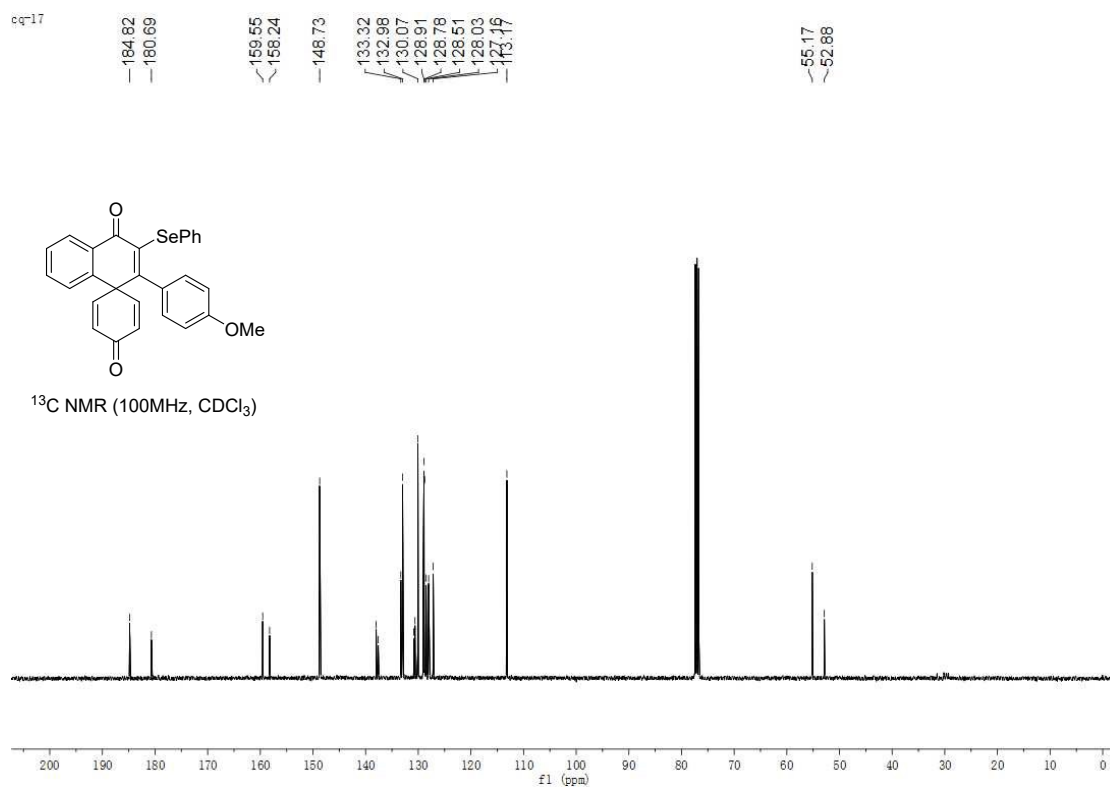
ca-17



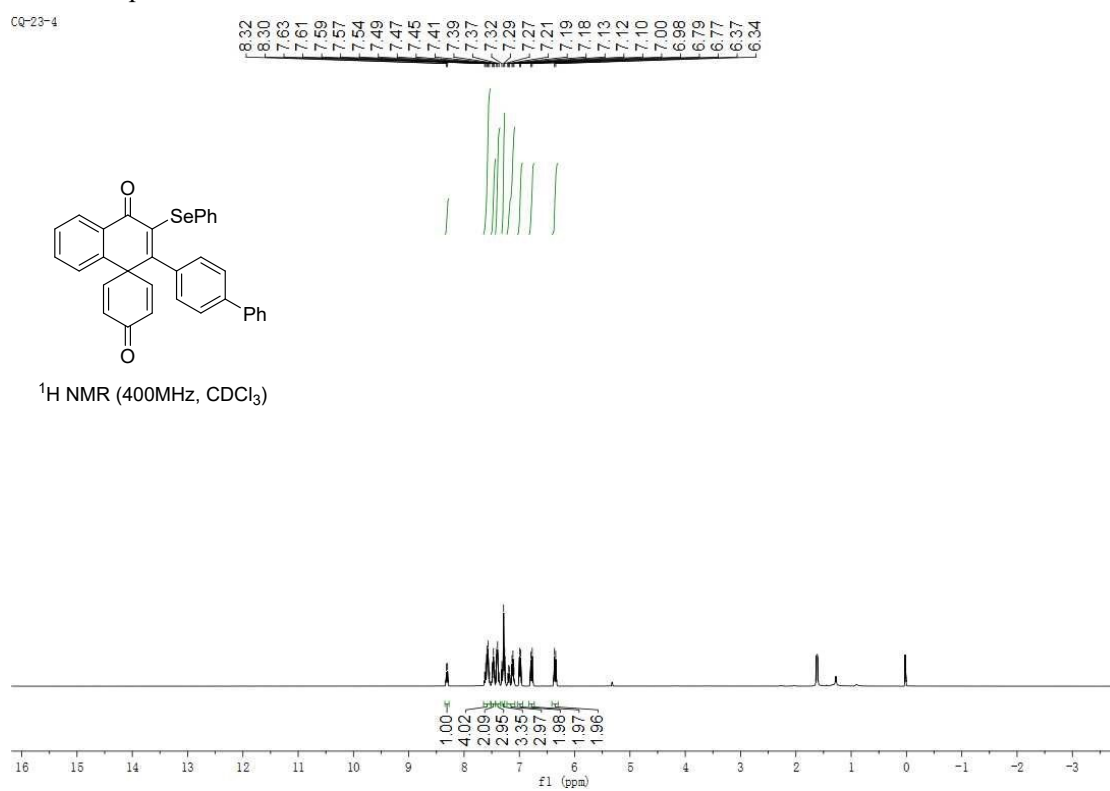
¹H NMR (400MHz, CDCl₃)



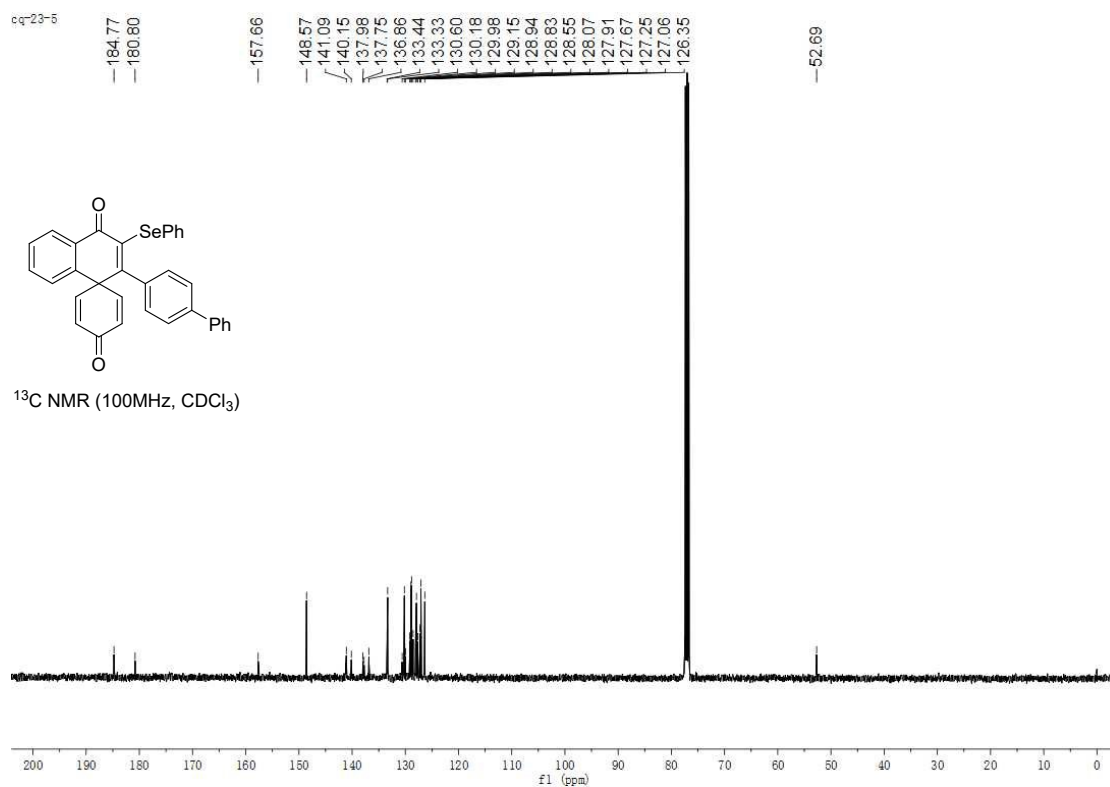
¹³C NMR spectrum of **3ca**



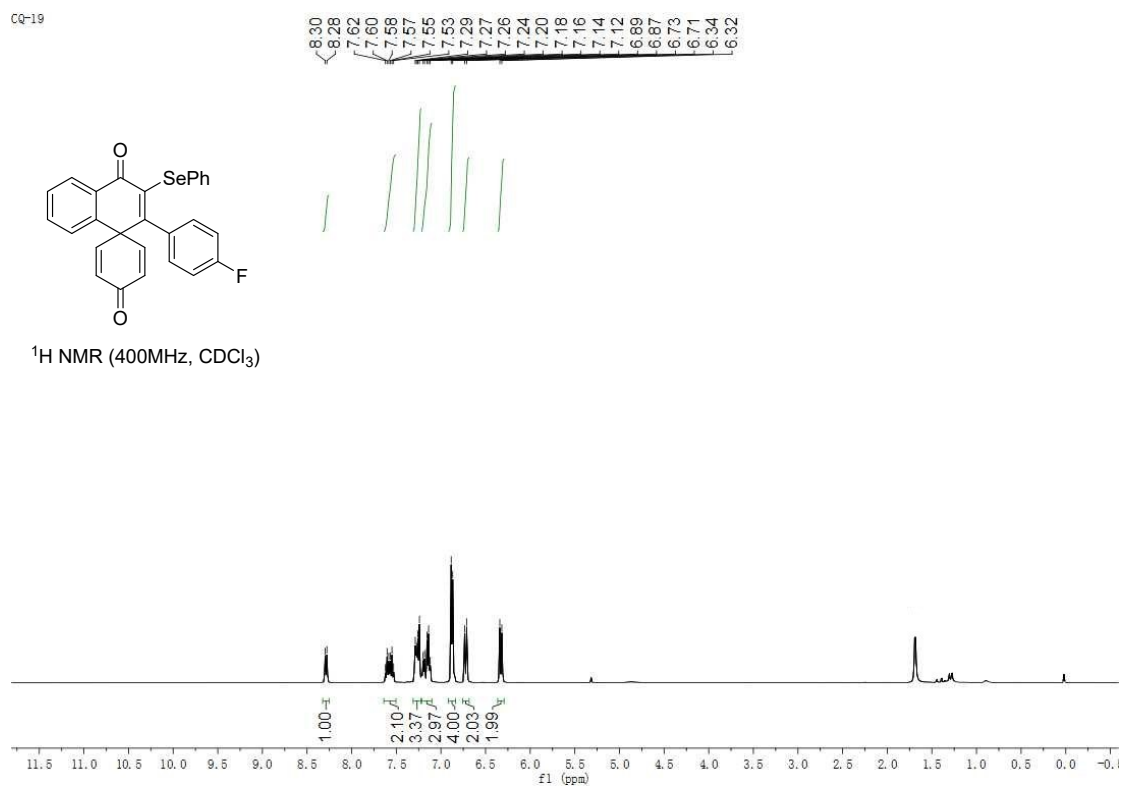
¹H NMR spectrum of **3da**



¹³C NMR spectrum of **3da**



¹H NMR spectrum of **3ea**



¹³C NMR spectrum of **3ea**

CQ-19

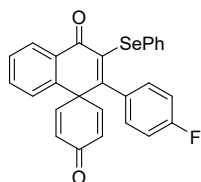
—184.54
—180.70

—163.65
—161.17
—156.76

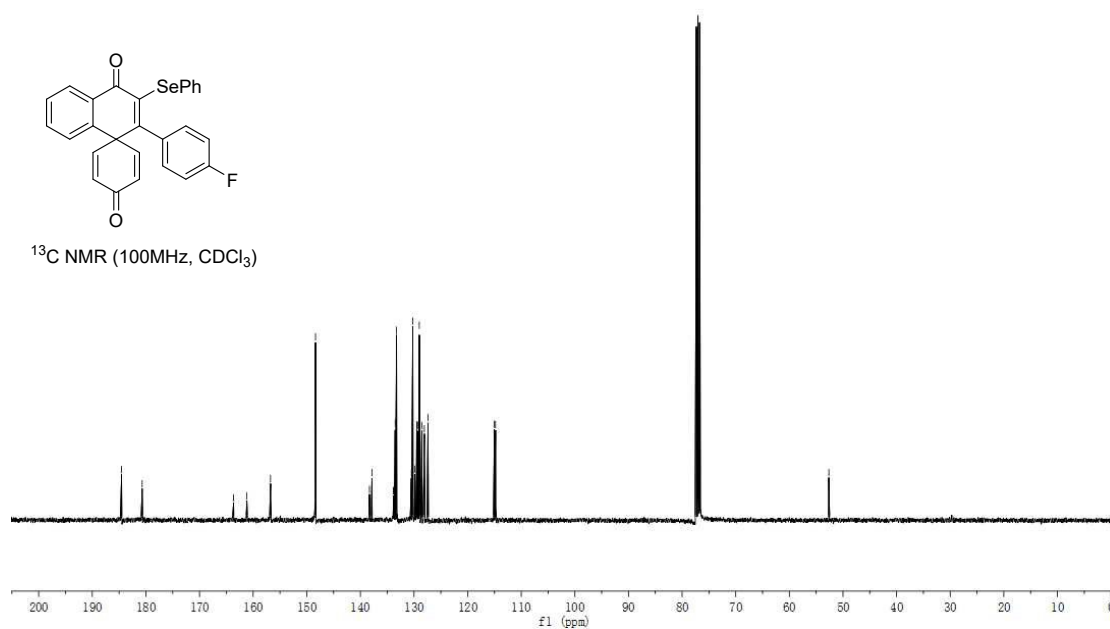
—148.37

—133.51
—133.25
—130.23
—129.49
—129.21
—129.02
—128.55
—127.82
—127.02
—114.80

—52.63



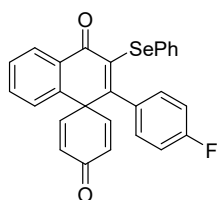
¹³C NMR (100MHz, CDCl₃)



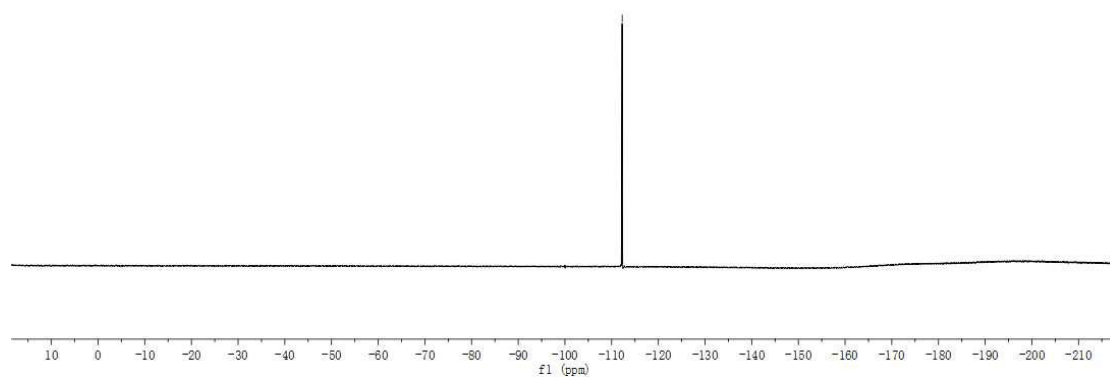
¹⁹F NMR spectrum of **3ea**

CQ-19

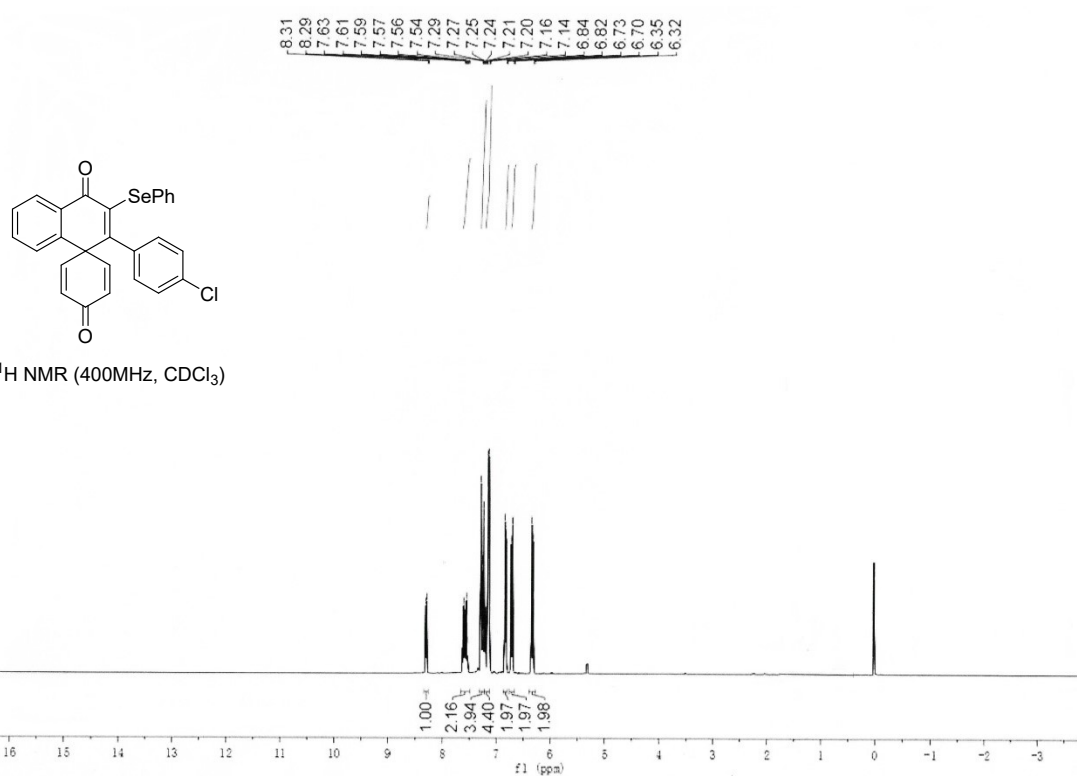
—112.26



¹⁹F NMR (376MHz, CDCl₃)

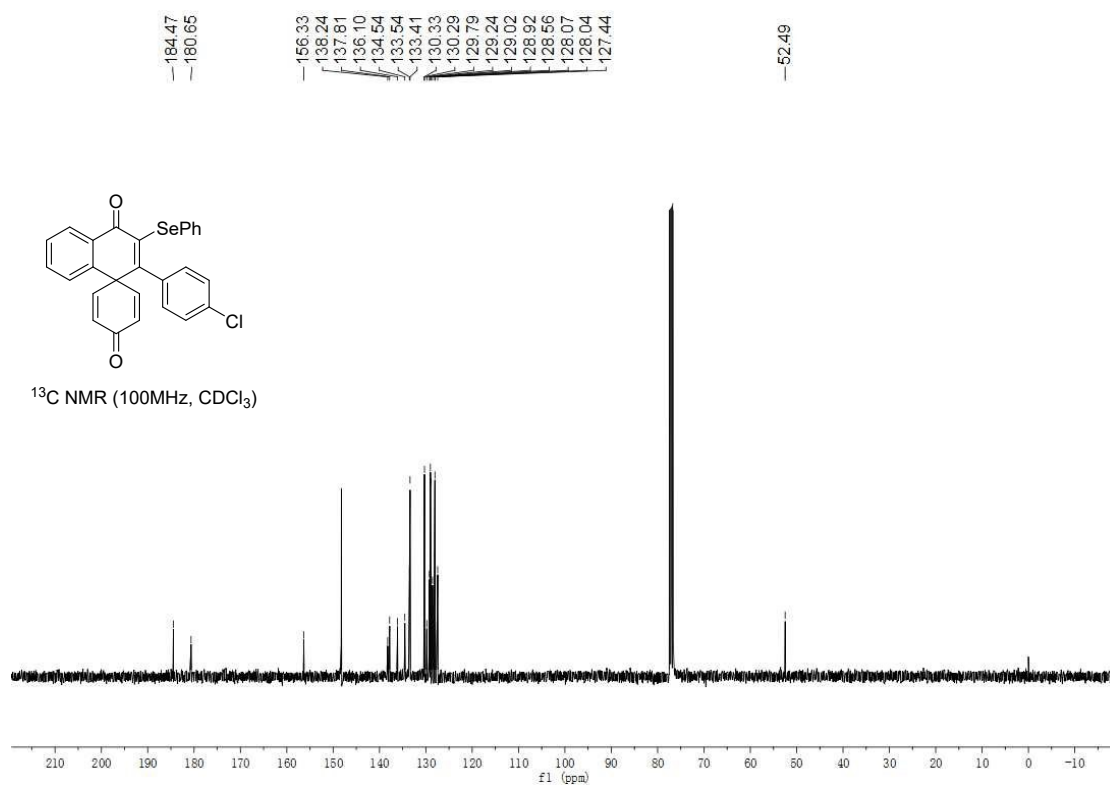


¹H NMR spectrum of **3fa**



¹H NMR (400MHz, CDCl₃)

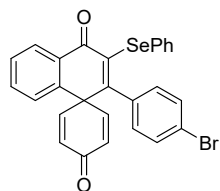
¹³C NMR spectrum of **3fa**



¹³C NMR (100MHz, CDCl₃)

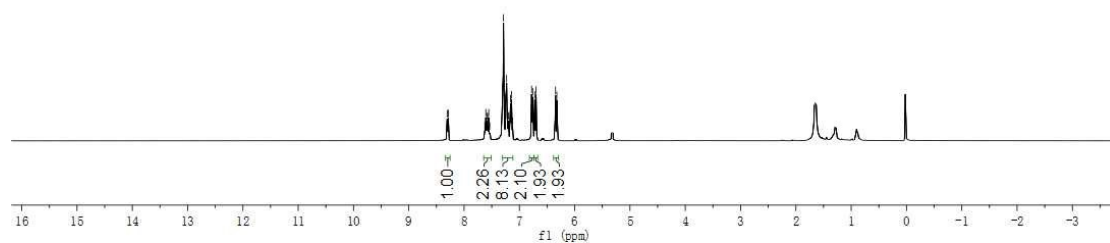
¹H NMR spectrum of **3ga**

CQ-24-4



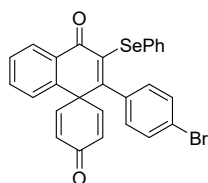
¹H NMR (400MHz, CDCl₃)

8.30
8.29
7.63
7.61
7.59
7.57
7.55
7.54
7.31
7.29
7.25
7.23
7.22
7.16
7.14
7.12
6.78
6.76
6.72
6.35
6.32



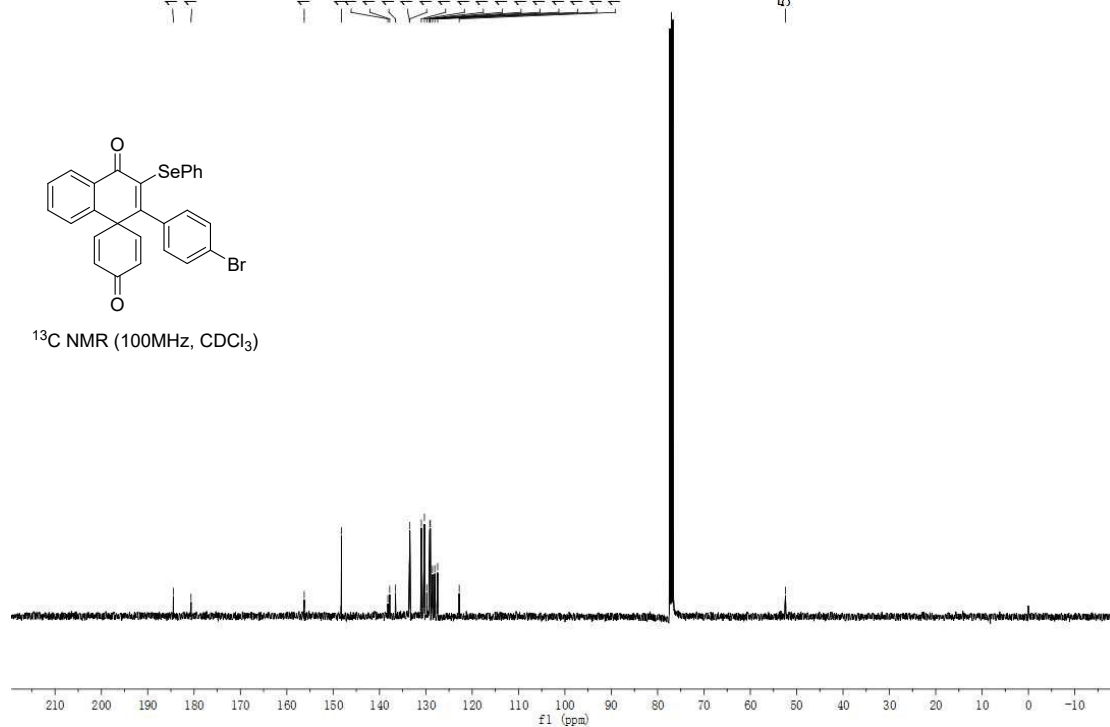
¹³C NMR spectrum of **3ga**

CQ-24-4



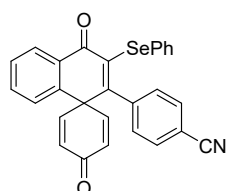
¹³C NMR (100MHz, CDCl₃)

184.47
180.66
156.24
138.20
137.80
136.55
133.54
133.45
130.97
130.30
129.78
129.24
129.15
129.03
128.56
128.07
127.45
122.80
52.42

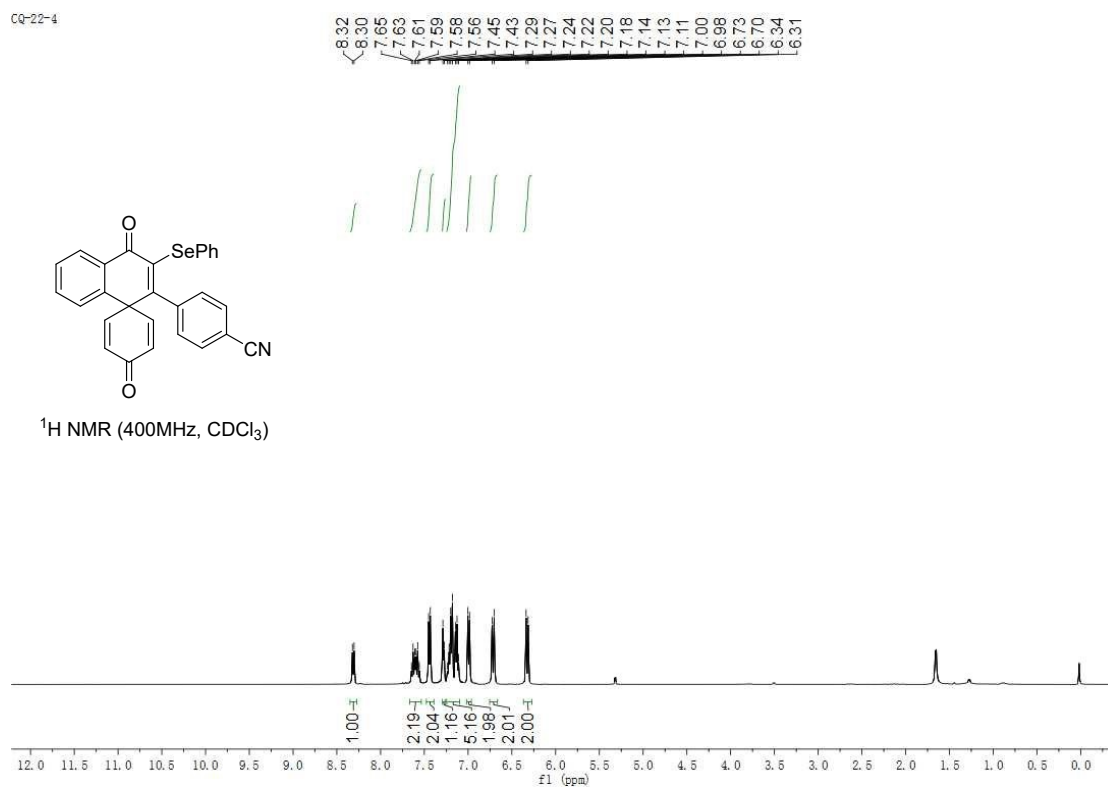


¹H NMR spectrum of **3ha**

CQ-22-4

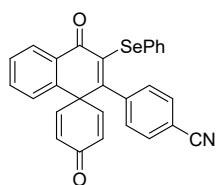


¹H NMR (400MHz, CDCl₃)

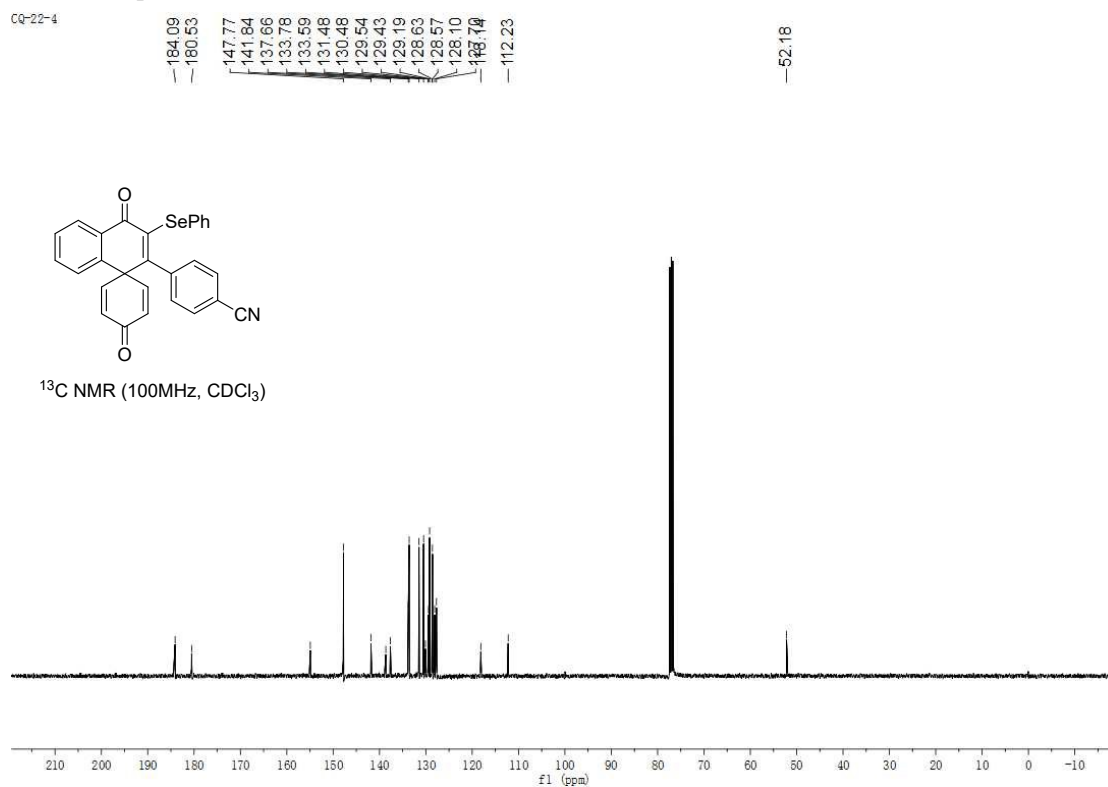


¹³C NMR spectrum of **3ha**

CQ-22-4

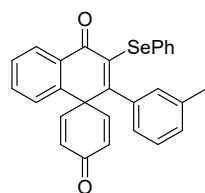


¹³C NMR (100MHz, CDCl₃)

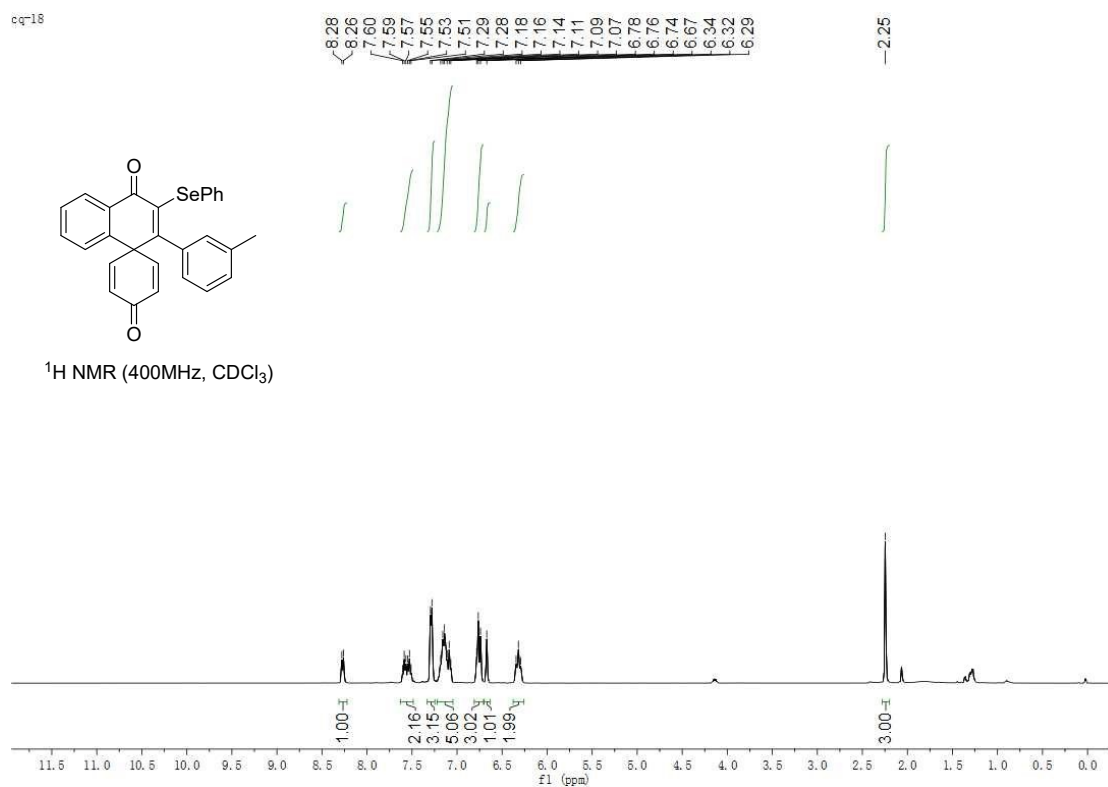


¹H NMR spectrum of **3ia**

cq-18

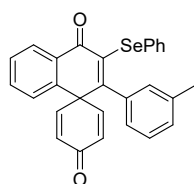


¹H NMR (400MHz, CDCl₃)

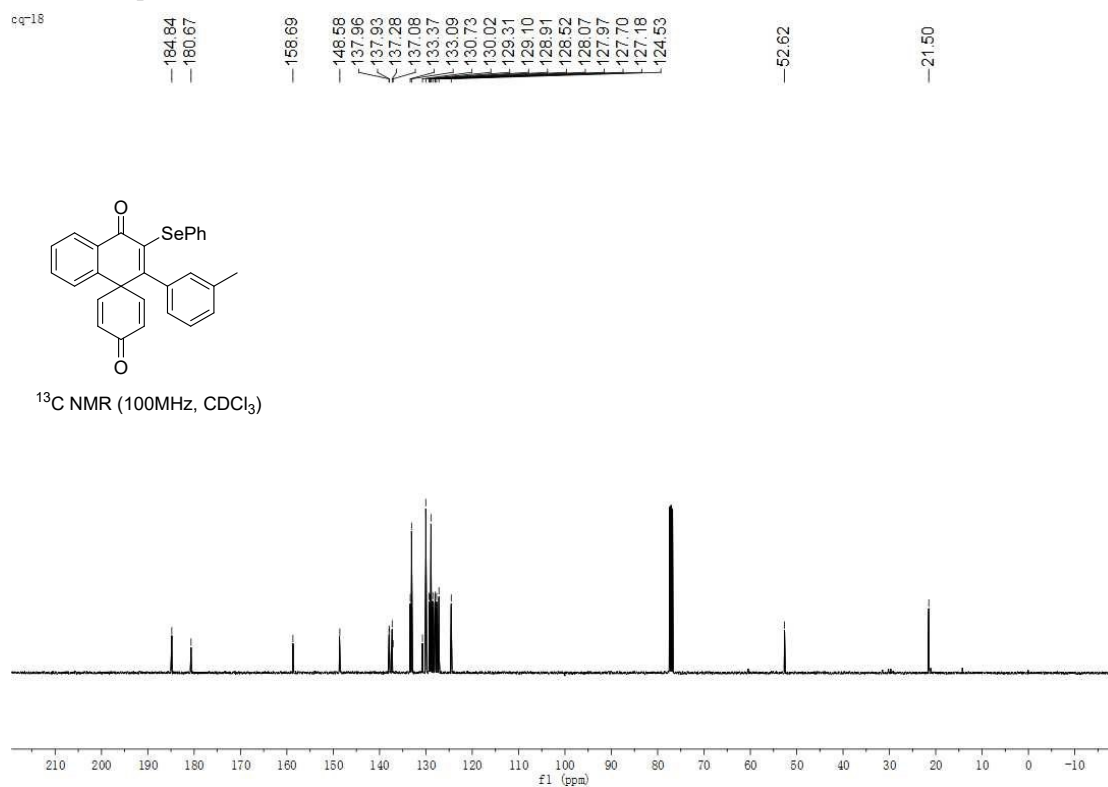


¹³C NMR spectrum of **3ia**

cq-18

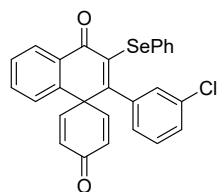


¹³C NMR (100MHz, CDCl₃)

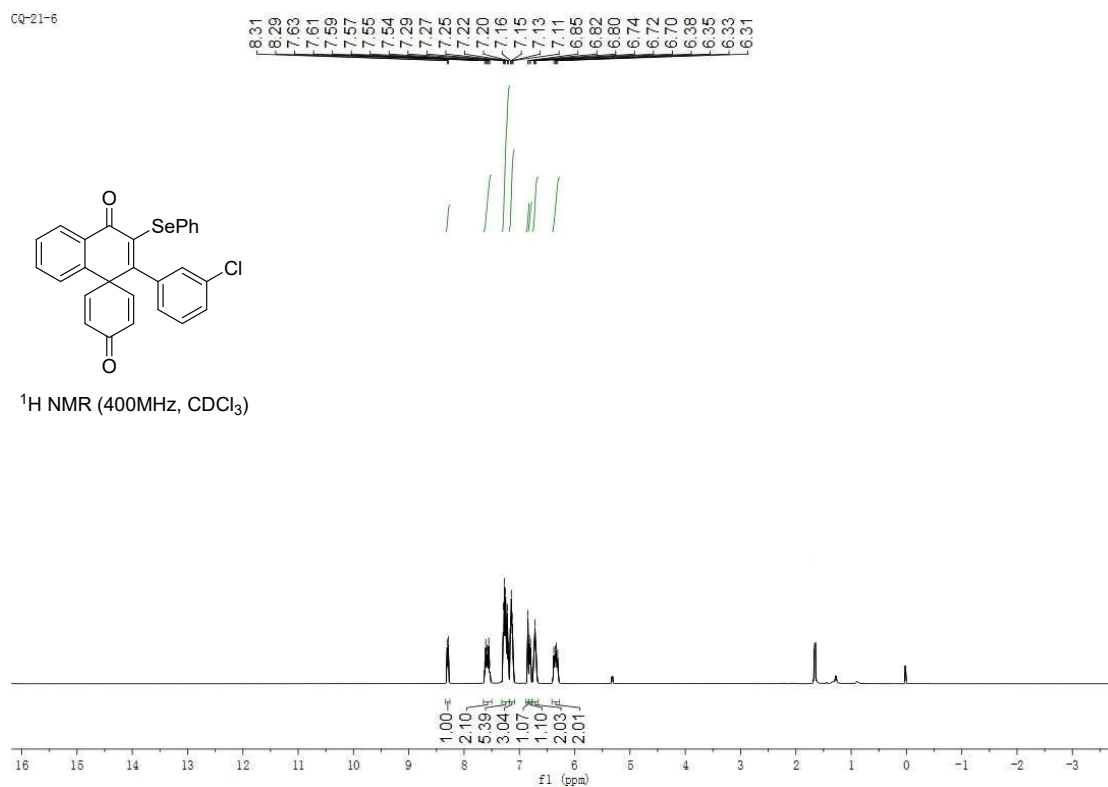


¹H NMR spectrum of **3ja**

CQ-21-6

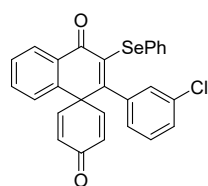


¹H NMR (400MHz, CDCl₃)

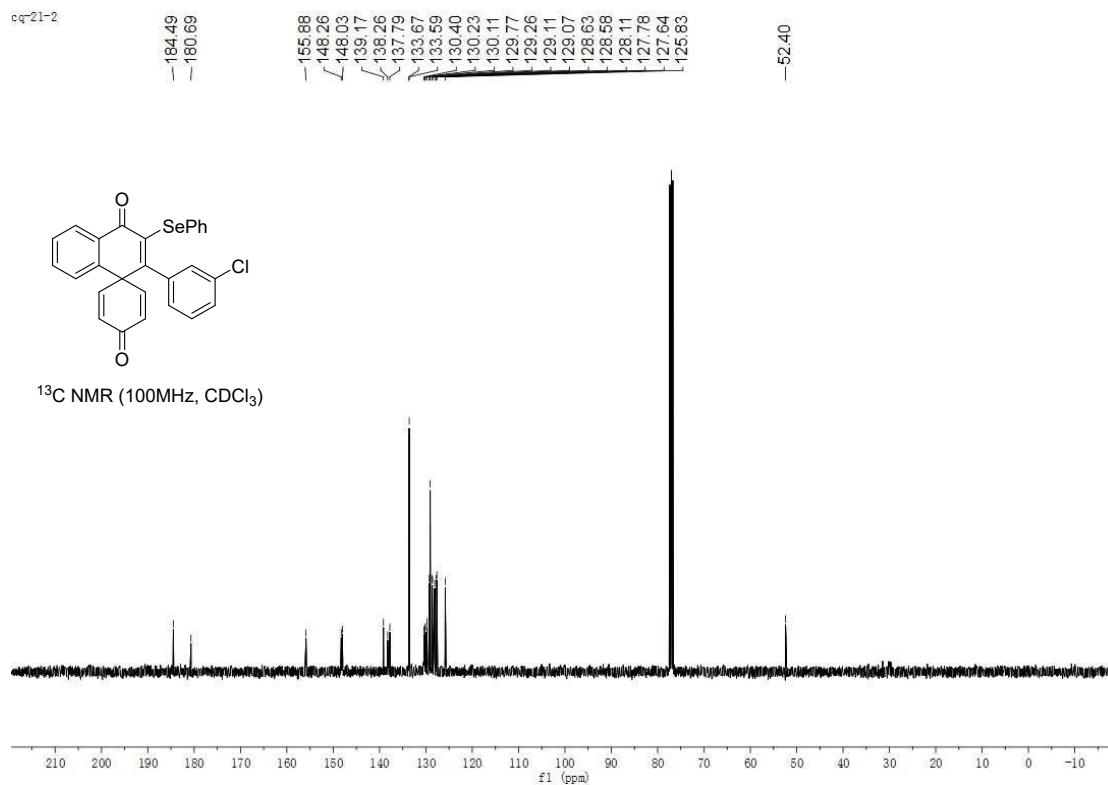


¹³C NMR spectrum of **3ja**

CQ-21-2

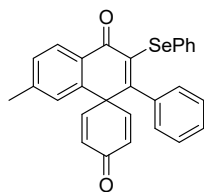


¹³C NMR (100MHz, CDCl₃)

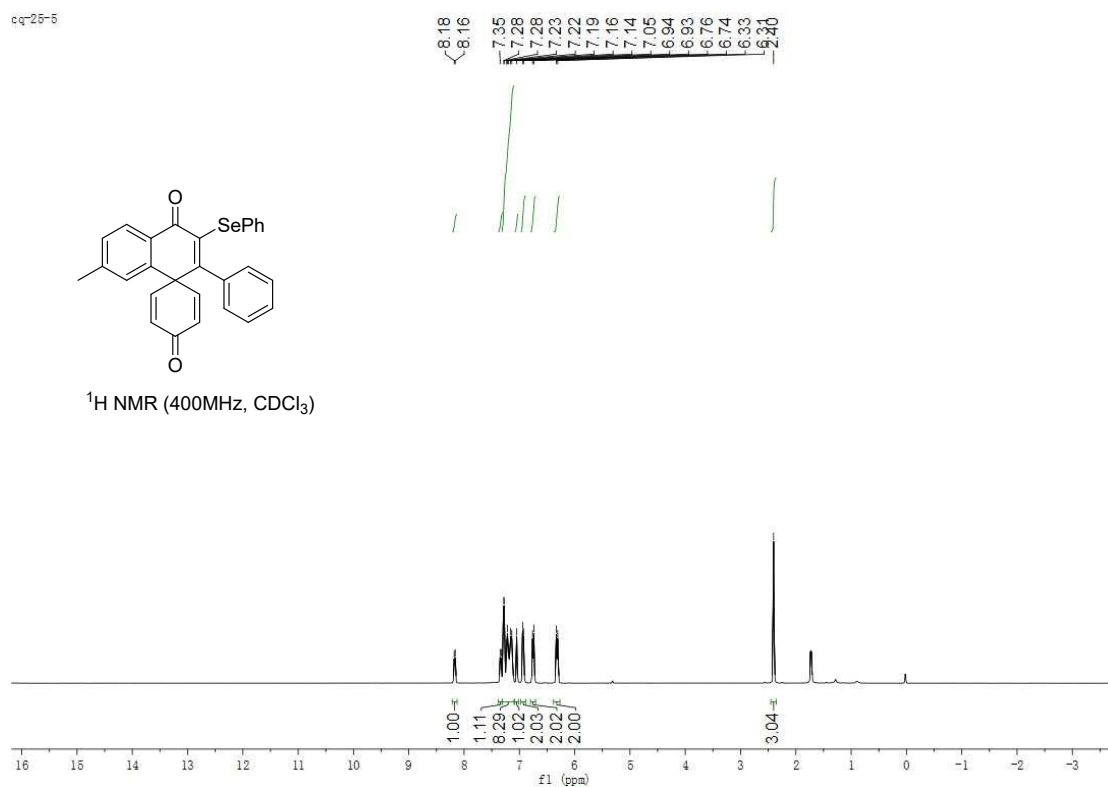


¹H NMR spectrum of **3ka**

cq-25-5

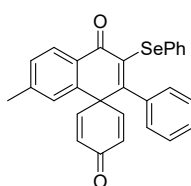


¹H NMR (400MHz, CDCl₃)

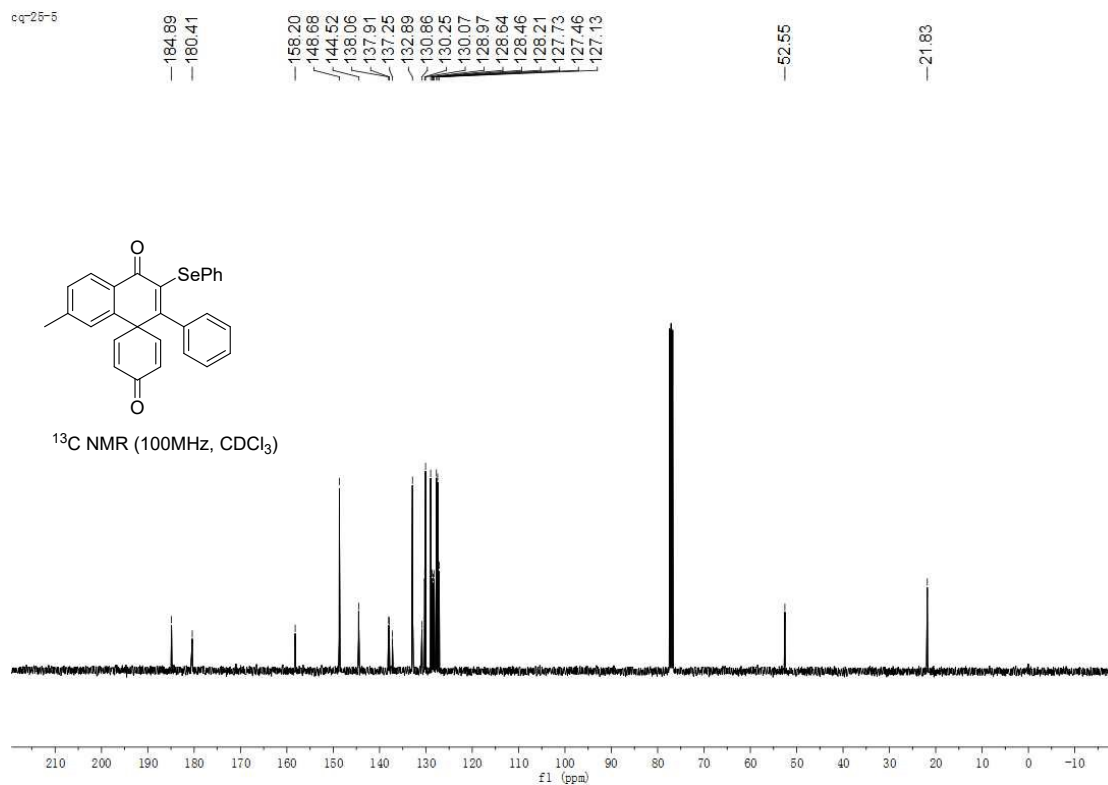


¹³C NMR spectrum of **3ka**

cq-25-5

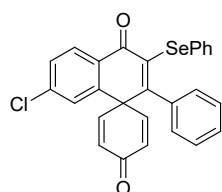


¹³C NMR (100MHz, CDCl₃)

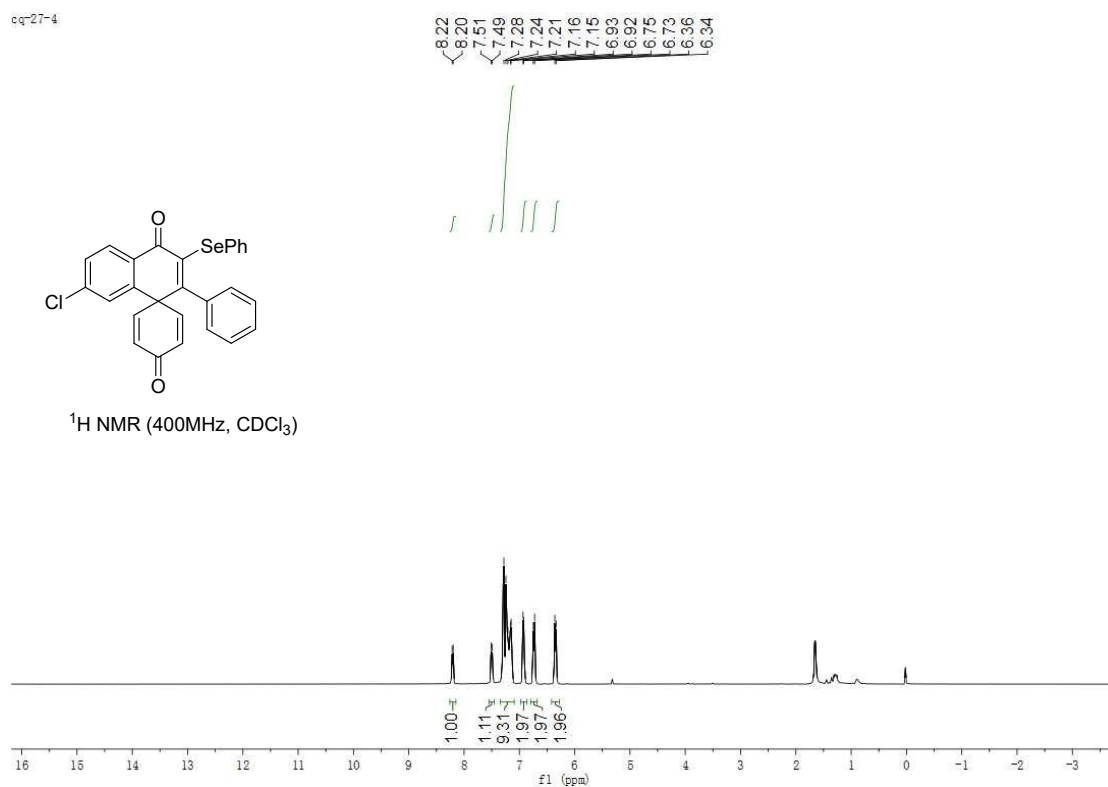


¹H NMR spectrum of **3la**

cq-27-4

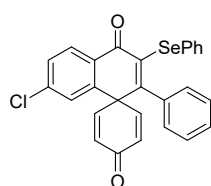


¹H NMR (400MHz, CDCl₃)

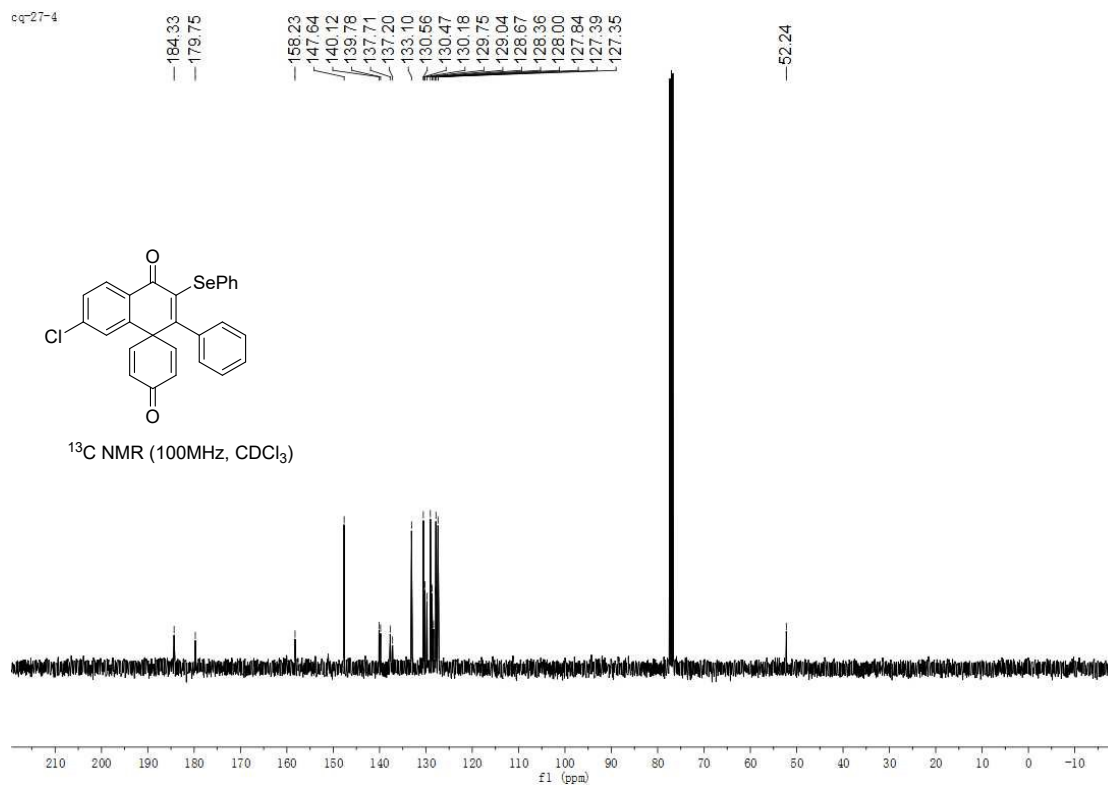


¹³C NMR spectrum of **3la**

cq-27-4

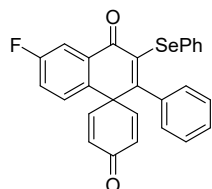


¹³C NMR (100MHz, CDCl₃)

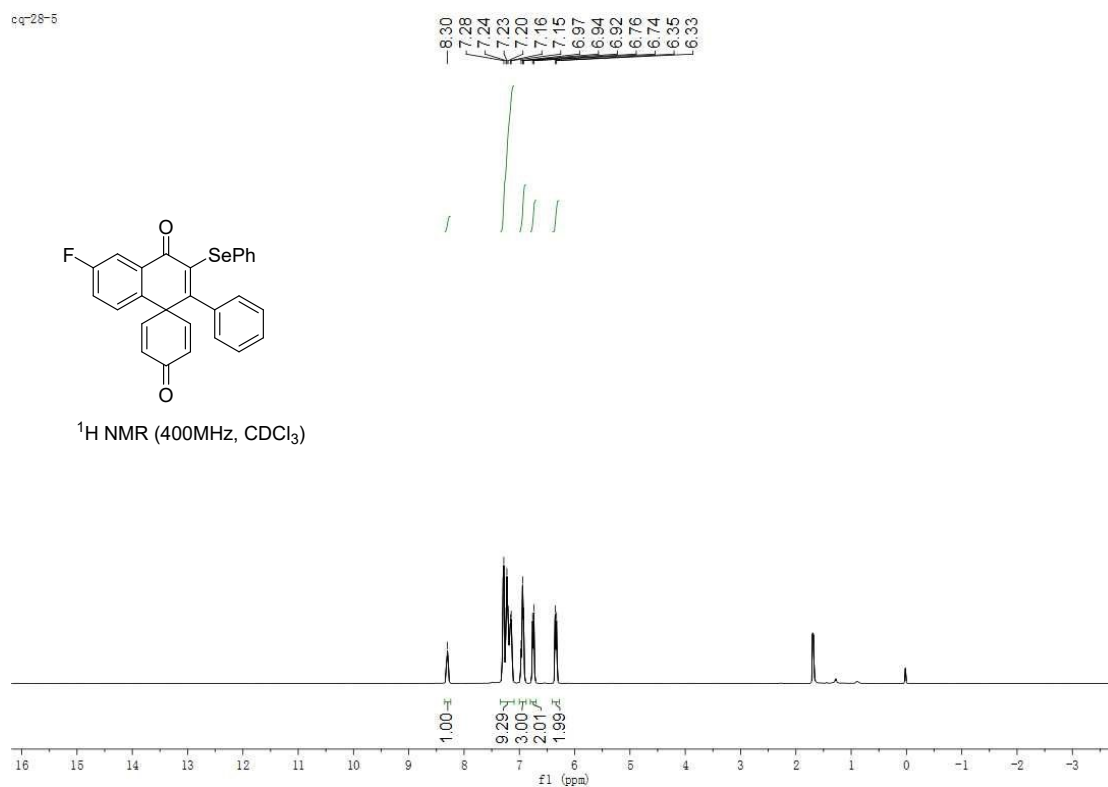


¹H NMR spectrum of **3ma**

cq-28-5

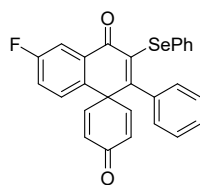


¹H NMR (400MHz, CDCl₃)

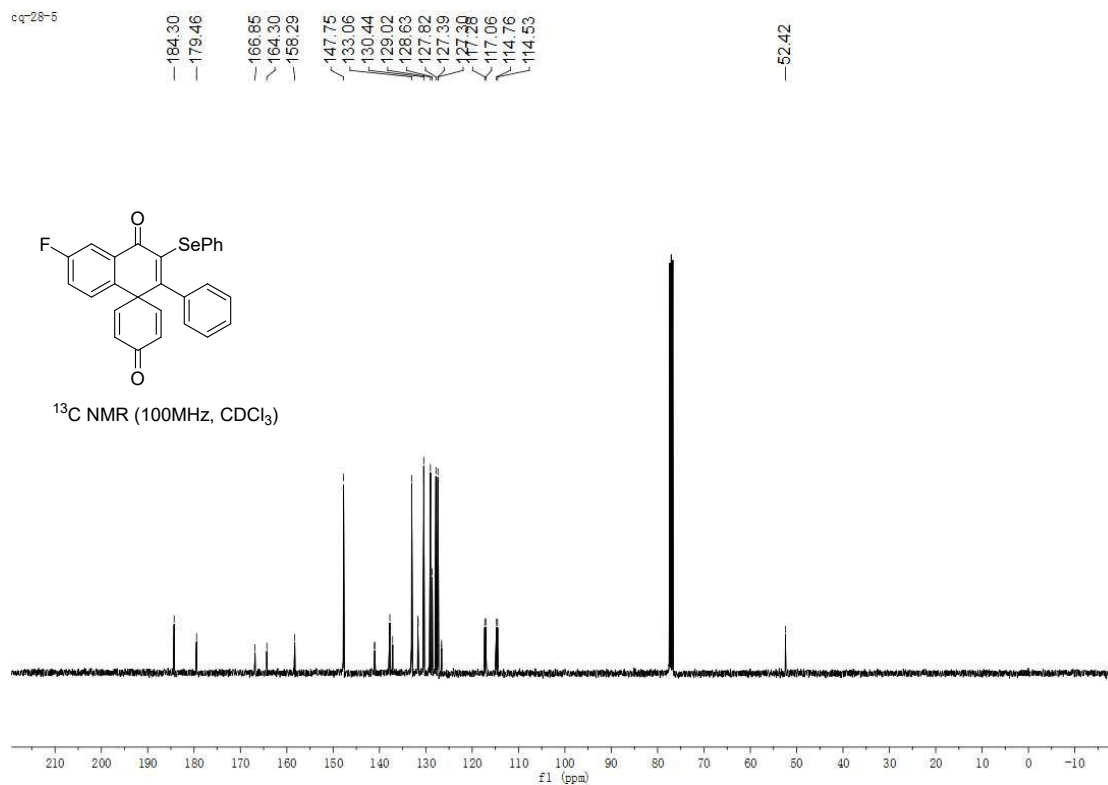


¹³C NMR spectrum of **3ma**

cq-28-5

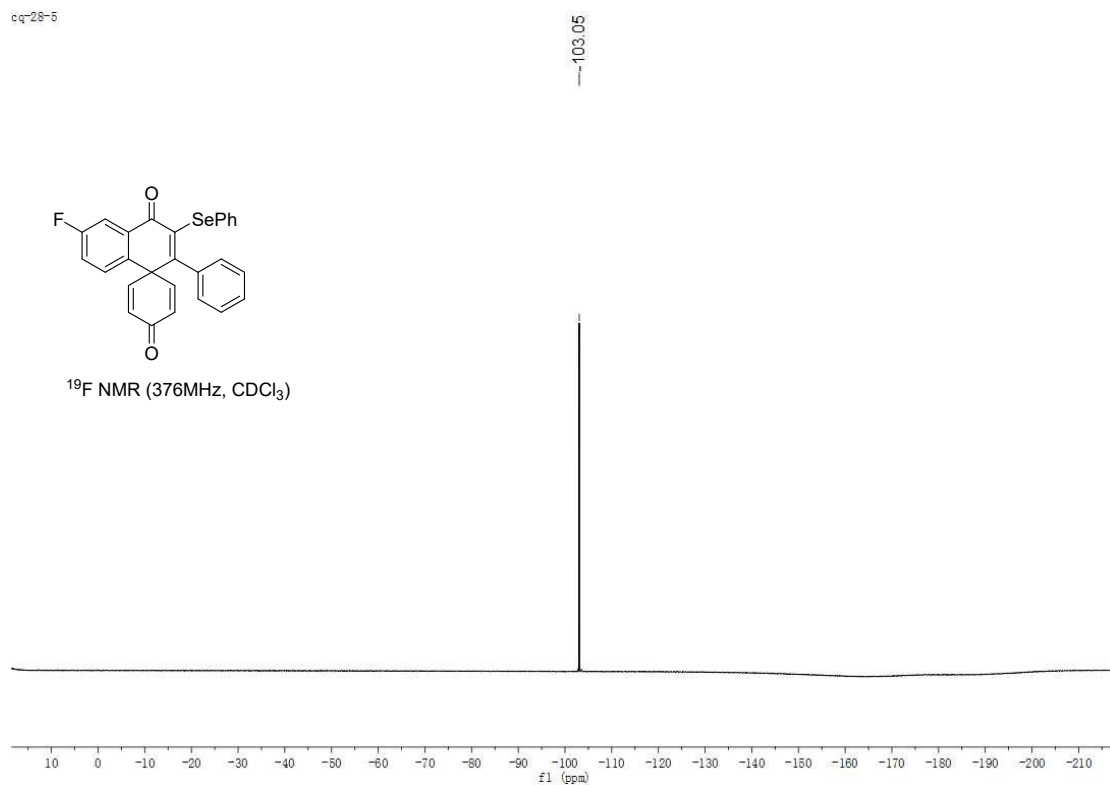


¹³C NMR (100MHz, CDCl₃)



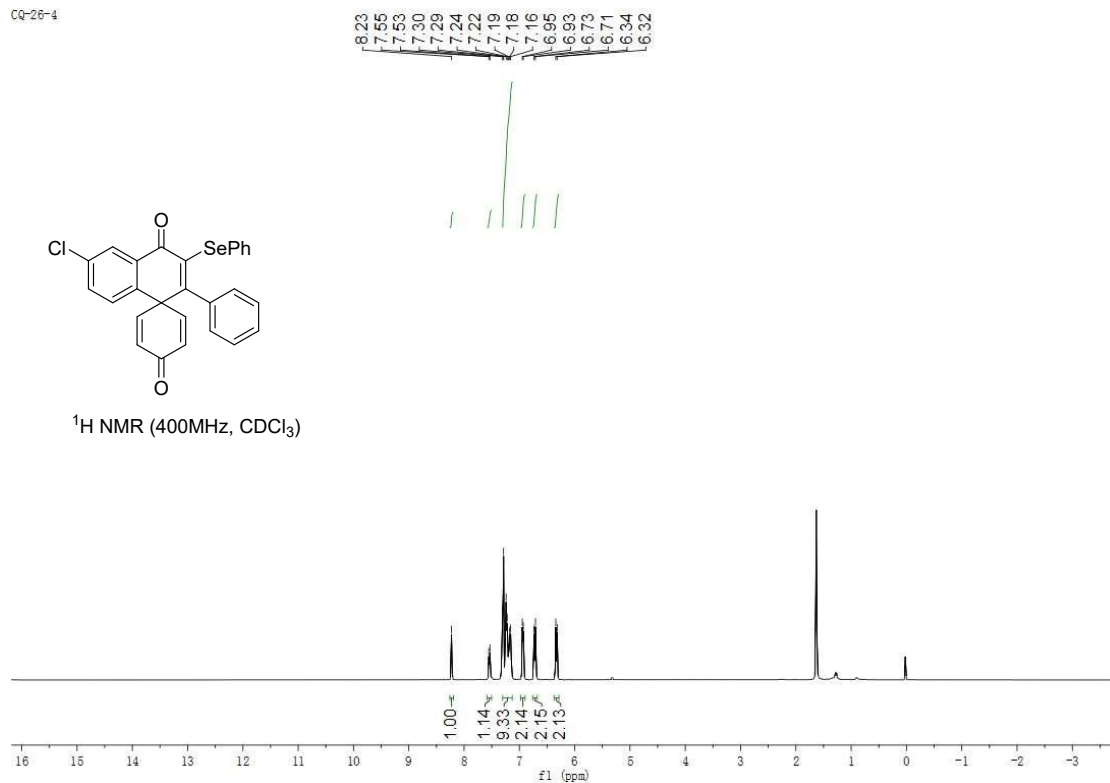
^{19}F NMR spectrum of **3ma**

cq-28-5



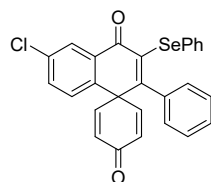
^1H NMR spectrum of **3na**

CQ-26-4



¹³C NMR spectrum of **3na**

CQ-26-4



¹³C NMR (100MHz, CDCl₃)

